SCIENCE AND ART DEPARTMENT
OF THE COMMITTEE OF COUNCIL ON
EDUCATION.

SCHOOL OF ART.

Carlisle

Presented to Edward Joshua Parker

for success in the Advanced Section of the Course of Instruction in Art.

BY ORDER OF THE LORDS OF THE COMMITTEE OF
PRIVY COUNCIL ON EDUCATION.
MDCCCLXXII.

PRINCIPLES

OF

THE SCIENCE OF COLOUR

CONCISELY STATED

TO AID AND PROMOTE THEIR USEFUL APPLICATION

IN THE DECORATIVE ARTS.

By WILLIAM BENSON, ARCH.T

LONDON:
CHAPMAN & HALL, 193, PICCADILLY.
1868.

{1872 issue}

To G. G. STOKES, M.A., D.C.L.,

SECRETARY TO THE ROYAL SOCIETY, AND LUCASIAN PROFESSOR

OF MATHEMATICS IN THE UNIVERSITY OF CAMBRIDGE,

THIS LITTLE TREATISE

IS BY HIS KIND PERMISSION INSCRIBED

IN ACKNOWLEDGEMENT OF

HIS MANY VALUABLE CONTRIBUTIONS TO SCIENCE,

AND OF

ASSISTANCE OBLIGINGLY RENDERED

IN THE AUTHOR'S INQUIRIES.

PREFACE.

In the following pages I have noticed those points only which seem essential to the theory and practice of colour, including some which have not hitherto received the attention they deserve. In recommending the use of the prism, an instrument indispensable to those who would learn to judge of colours correctly, I have pointed out how, by a simple experiment with it, we may produce at will all possible hues, in all their tints and shades, with the nearest possible approach to perfection, and present them at once to the eye; and how, by another, we may see any of these colours in juxtaposition with its perfect complementary, and may also learn to compare the luminosity or brightness of colours differing in hue.

The beautiful method of finding colours intermediate between any two given colours, by the aid of a slip of polished glass, used by Lambert in his Photometria (Berlin, 1760), but strangely neglected since, is then stated; an easy way to discover the true mean is pointed out; and the difference between the results thus obtained, and the effects of the mixture of pigments, explained.

What has now for some years, I believe, been admitted by scientific persons as the true doctrine concerning the simple or elementary sensations of colour, is next laid down, instead of the very incorrect theory still generally repeated in popular and elementary treatises. The diagram which I have given of the principal colours, notwithstanding the imperfection in hue and inequality in strength of the pigments used, will I hope speak for itself in commending this doctrine to the eye, and help to overcome the natural bias of many in favour of what they have hitherto assumed to be unquestionably true, though unsupported by a single rational experiment. The necessary double brightness of the secondary colours, when of full strength, on which so much of their beauty depends, and which is neglected in schemes founded on the mixture of pigments, is here particularly noticed; and the importance of bearing this in mind has induced me to use the term Pink, instead of Purple, for the secondary containing Red and Blue; especially as the colour commonly understood by the latter contains a great preponderance of Blue, besides being much too dark.

Observations are added on the qualities of colours, especially in defining and distinguishing what I have called their depth and clearness; on the reasons why some may excel in one of these qualities, and others in the other; and on the extent of this difference. These may lead to rules concerning the proportions in which colours may neutralize each other, more reliable than those which Field so hastily laid down from his experiments on the superposition of coloured glasses or solutions, the results of which he totally misunderstood, since the thicknesses of the coloured substances upon which he experimented indicated anything rather than the quantities of the respective colours in the transmitted light.

A complete but very simple system of colours is next proposed, on the true theory of the three elementary colour-sensations, and on the only principle on which all possible combinations of those sensations can be correctly arranged according to their natural relations (a principle which I have since found was suggested more than forty years ago by Sir John Herschel, in his Treatise on Light in the Encyclopœdia Metropolitana). This will be useful in classifying and grouping different kinds of gradations and contrasts, and in helping the artist to devise endless varieties of beautiful arrangements of colours.

In the remainder of the work the ocular modifications of colours, their mental effects, and the doctrine of the harmony of colours, are very briefly handled; but on each of these will be found, I think, some new considerations, tending to enlarge, correct, or simplify what has been advanced in previous works on this subject.

Should this treatise, notwithstanding the many defects I am sensible of, both in itself and in the coloured illustrations which accompany it, prove acceptable to a discerning public, I hope to publish a larger work, already prepared, on the same subject. The plan and contents of that work are appended, and, to those who have not studied this branch of science, will give some idea of what has been done to elucidate it, both in other countries, and in our own.

147, Albany Street, Regent's Park, London, N.W.
29*th May*, 1868.

ADVERTISEMENT TO THE ISSUE OF 1872.

Since this treatise was published the truth of the theory of the three colour-sensations has been confirmed by further careful observations on the colours of the spectrum made in a new way by J. J. Müller in Germany, which leave no reason to question the conclusions previously arrived at. The nature also of the common peculiarity of colour-vision, called dichromism, has been more clearly elucidated, and the subject much simplified, by Professor J. Clerk Maxwell, who in a lecture at the Royal Institution (24 March, 1871) showed cause to believe that it is nothing more than a total incapacity for the sensation of red; so that dichromists may be regarded as seeing all colours just as others would see them, subtracting the red element in each. And when one has learnt correctly the composition of the different colours, that is in what proportions the red, green, and blue sensations are combined in them, one can easily tell what colour any given object appears to such persons, and why the colours of objects to others so different are alike or the same to them. The observations on Dichromism in Chapter XII. therefore require correction in this respect, and so do those made on the same subject in Chapter VIII. of my Manual of the Science of Colour (1871).

Several persons have taken exception to the use of the term Blue to denote the third colour-sensation. They understand by that term a colour which contains a large admixture of green, and think that Violet would be a preferable term; but though it is true that Blue in the English language is frequently applied to colours which approach to seagreen, yet it is certainly not incorrect to apply it to the colours of the whole of the more refrangible part of the spectrum to the very end. The term Sea-green has also been objected to, but I have not heard a better term suggested for the colour for which I have used it. I would here mention that in several cases other pigments than those mentioned on page 31 have been used in colouring the illustrations. Ultramarine, or "French Blue," with or without Zinc white, is better for both full blue and light blue than Cobalt, its hue being more distant from green. "Permanent Yellow," toned with a little Chrome, makes a yellow as good as that of "King's Yellow," and not liable to change; a mixture of Scarlet Vermilion with Rose Madder is used for pink-red; and a mixture of the same with Indian Lake for dark red. Seagreen and light seagreen are represented by mixtures of "Emerald Green" with Cobalt and "Ceruleum"; dark seagreen by a mixture of the same with "Cyanine Blue."

WEST STREET, HERTFORD,
2nd Sept., 1872.

ERRATA.

In page 28, in the middle of the central column, for *Light yellow* read *Light green.*

In page 29, near the foot of first column, for *Light red* read *Light pink.*

In page 30, in the middle of the first column, for *Light green* read *Yellow green.*

CONTENTS.

LIST OF ILLUSTRATIONS.

[The binder will distinguish the five coloured Plates by the descriptions of their colours on the pages which they are to face. The top of each is that edge nearest to which the white circles lie].

Ἔστι δὲ τὰ χρώματα ταῦτα, ἅπερ μόνα σχεδὸν ὀυ δύνανται ποιεῖν ὁι γραφεῖς. Ἔνια γὰρ αὐτὸι κεραννύουσι· τὸ δὲ φοινικοῦν καὶ πράσινον καὶ ἁλουργὸν ὀυ γίγνεται κεραννύμενον· ἡ δὲ ἶρις ταῦτ' ἔχει τὰ χρώματα.

"The colours of the rainbow are those which, almost alone, painters cannot make. For they compound some colours; but Scarlet and Green and Violet are not produced by mixture, and these are the colours of the rainbow.

ARISTOTLE, *Meteorologica*, iii., 2.

PRINCIPLES

OF THE

SCIENCE OF COLOUR.

CHAPTER I.

THE NATURE AND CAUSE OF COLOURS.

Colours are merely sensations produced by the action of light on the nervous tissue of the retina, which covers the back of the eye.

The ordinary white light of the sun contains an infinite variety of different kinds of homogeneous light, differing essentially from each other in nothing but the period of the etherial undulations of which all light consists; and each of these different kinds of light, when it enters the eye so as to fall alone on any part of the retina, excites there a peculiar sensation of colour.

When several of these different kinds of light fall on the retina together, they produce a sensation which is made up of all those sensations which they would produce separately, if they entered the eye after separate intervals of time, or fell on different parts of the retina; in other words, their colour is the sum of the colours of all the component lights.

When the intensity of the light is increased or diminished, without altering its nature, or the proportions of its components, the brightness of its colour increases or diminishes. Hence arise all the shades of colours, from the utmost brightness, down to black, the absence of all light.

The variety of colours in natural objects, illuminated by the same white light of the sun, arises from peculiarities in the constitutions of those objects, causing them to transmit or reflect to the eye some kinds of light in larger proportions than others.

In the vast majority of instances, whatever light is reflected from their surfaces consists of all the ingredients of the incident light in equal proportion, and is therefore of the same colour as the incident light. But, in general, a large part of the incident light enters the body, and of this part some of the ingredients are often more powerfully absorbed, and therefore sooner extinguished than the rest; so that if, after traversing a certain thickness, any of it emerges and reaches the eye, it is no longer of the colour of the incident light.

In this way not only transparent and pellucid substances, seen by light which has passed through them, but also pigments and most other bodies seen by reflected light, derive their proper colours; for, disregarding the light reflected from the surface, which varies in quantity with the angle of incidence, the colour depends on that reflected from some depth below the surface, so that it has traversed twice a small thickness of the absorbing substance, where part of the original light has been lost. All colours caused by absorption vary in general with the thickness of the substances traversed, in consequence of the unequal rates in which the differently colored rays are absorbed. If all the light that enters is destroyed, the body is of course Black, excepting the superficial reflection. If the incident rays of all sorts are absorbed in equal proportion, large or small, the body is Gray or White.

Superficial reflection is usually small, except at very oblique incidences; but in some instances, as in silver and other metals, it is so intense that the body is lustrous from that cause alone. There are also bodies which reflect superficially some kinds of light more copiously than others, as gold and copper, and some few non-metallic substances, as compressed Indigo, which have in consequence a sort of metallic appearance.

The varying colours of finely-striated surfaces, as in mother-of-pearl, and those of thin laminæ, as in peacocks' feathers and butterflies' wings, are produced by the mutual interference of luminous undulations, whereby the different kinds of light are alternately strengthened and destroyed in different positions, according to their wave-lengths.

CHAPTER II.

THE PRISMATIC COLOURS AND THEIR CONTINUOUS COMBINATIONS.

To see at one view the hues which distinguish the different kinds of homogeneous light, the best way is to cause a beam of the light emitted by the sun or by any other bright luminous object which emits light of all possible wave-lengths, to pass through two inclined faces of a prism of some powerfully refracting medium, such as flint glass, and then to reflect it from a white screen to the eye, or to receive it directly in the eye, all other light being excluded. For the less the wave-length the more is the light, on emerging from the prism, bent out of its original direction; and thus each different kind occupies a different place on the screen, and enters the eye in a different direction, so as to affect a separate part of the retina, producing the splendid series of colours known as the prismatic spectrum.

In such a spectrum, therefore, we have an orderly exposition of the colours proper to all the different kinds of homogeneous light. When precautions are used to obtain a tolerably pure spectrum,* these colours are at once seen (except by persons of dichromic or of defective colour vision, the peculiarities of which will be noticed in an appendix) to constitute three conspicuous bands; the least refrangible rays (or those of the longest waves) being Red; the middle band, Green; and the most refrangible rays (or those of the shortest waves) being Blue. A closer inspection however shows that the colours are not uniform in the bands, but change gradually both in brightness and in hue.

* If the spectrum is to be reflected from a white ground, then to make it as pure as possible the sun beam should fall on the prism in a narrow line, parallel to one refracting edge, all other light being excluded from the room; and the face of the prism should be so inclined to the sun beam as to divert the emergent rays as little as possible from their original direction. If the spectrum is to be received directly into the eye, the line of white light to be viewed must be also as narrow as possible without too much diminishing the light, or must be viewed at a distance through a large prism, in which case it must be bordered on both sides with a great breadth of total blackness; care must be taken also to shade the eye and the prism form all other light.

The series begins with dark Red, which first becomes bright Scarlet and then passes through Orange into still brighter Yellow, and then through Yellow-green into Green ; the Green then changes through a dullish Seagreen into Blue, and this deepens and fades away into darkness through a faint tinge of Violet; the colour of the last rays thus seeming to tend towards the redness of the first.*

By adding different rays together, additions of their several colours are made. The strongest Red and Green and Blue are obtained by throwing together all the rays in which these colours respectively predominate, and excluding the rest. The strongest Yellow is produced by combining the Red and Green rays, and excluding the Blue; the strongest Sea-green by combining the Green and Blue rays, and excluding the Red; the strongest Pink by combining the Red and Blue rays, and excluding the Green. When part only of the third band in each case is excluded, the resulting colour is brighter but paler, until when all are included the pure White of the solar light is obtained.

The colours produced by successive continuous additions of the prismatic rays, beginning either at the Red or at the Violet end of the spectrum, may be beautifully seen by viewing through a prism the nearer or further edge of a white space against Black. The first set contains the best Red, Orange, and Yellow, which last, by addition of Blue, passes into White; the second contains the best Blue, Seagreen-blue, and Seagreen, which last again passes, by addition of Red, into White.

The same results are obtained by analysis; for just as all the three bands are obtained by viewing through the prism a bright white line against a black ground, so are the Red and Green bands obtained by viewing, in like manner, a Yellow line, as for example, one coloured with King's Yellow; the Green and Blue bands by viewing a Seagreen line, as one coloured with Verdigris; and the Blue and Red bands by viewing a Pink line, as one coloured with Rose Madder; and lastly, the Red, the Green, or the Blue band, is seen alone, when a Red, a Green, or a Blue line, as for example, one coloured with Vermilion, with Emerald Green, or with Cobalt, is so viewed.

Since the colours of all natural objects are merely the sensations produced by those of the incident rays which they send to the eye, it is evident that every one of them must be produced by some mixture of prismatic rays, and that such colours must therefore be compositions of the prismatic colours. In every case

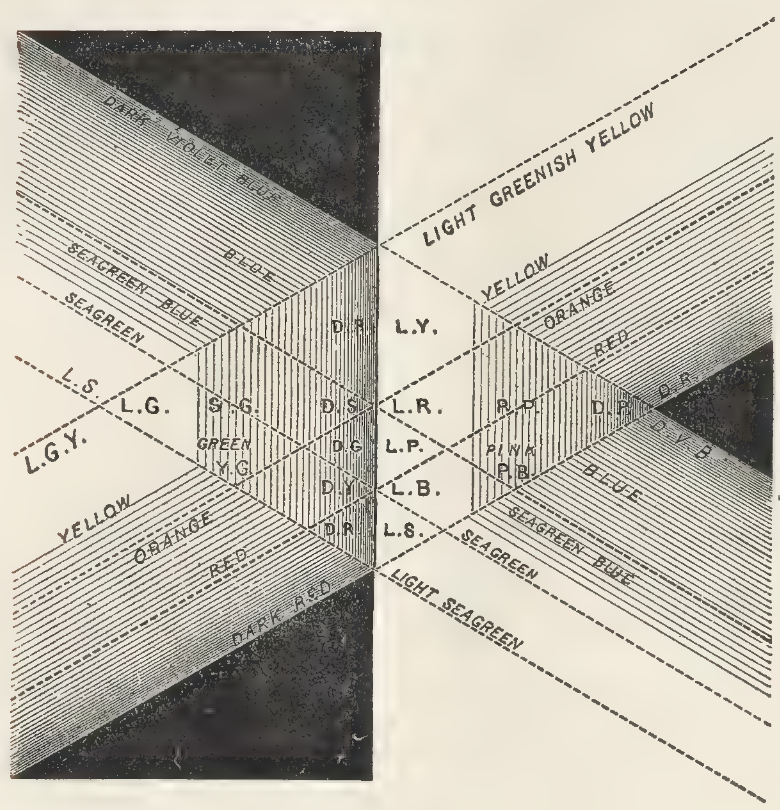
* Newton's celebrated division of the prismatic colours into Red, Orange, Yellow, Green, Blue, Indigo, and Violet, only differs from the above in not specifying the Yellow-green and the Seagreen (the former of which was included in his Yellow, and the latter partly in his Green and partly in his Blue), and in calling the deep dark Blue, Indigo.

the best colours are produced by rays which belong to some one continuous portion of the spectrum, beginning either at the one extremity or at the other, or at some intermediate point, or (in the case of Crimsons, Pinks, and Purples) by two such portions, one at one end, and the other at the other, all thrown together in their full intensity, while the rest of the rays are totally extinguished. It is easy to see that this must be the case, because the colours of the prismatic rays change gradually from end to end of the spectrum; and it is shown by analysing the colours of natural objects with the prism, and comparing the result with the spectrum of white light (which is easily effected by viewing through the prism, over a dark cavity, a stripe of the colour continuous with a stripe of White). Such experiments, however, show that the best natural colours are inferior to those which may be produced by artificial combinations of the prismatic rays, since there is no substance which transmits, without diminution, all the rays of any one portion of the spectrum, and totally absorbs or extinguishes all the rest.

By one simple and beautiful experiment with a prism, it is possible to present to the eye, not only the prismatic colours themselves in their greatest possible purity, merging into darkness, but also the colours of all possible parcels of continuous prismatic rays, forming an ensemble of the loveliest colours which the eye can behold. We have only to produce the spectrum of an angular space of White upon a black ground, meeting an angular space of Black upon a white ground, as in the following diagram, by means of a prism fixed parallel with the plane of the diagram, and at right angles with the medial line dividing the black and white grounds. The prism having its refracting edge directed away from the spectator, and being at such a distance from the object, that a small spot only of White appears amongst the colours to the left of the medial line, and one of Black amongst those to the right, the resulting colours are arranged according to the scheme which accompanies the diagram.

It is easy to see that the central lozenge-shaped space in the spectrum must contain all the colours spoken of. For the left half of the spectrum is formed by the overlapping of a series of angular spaces of the several prismatic colours, so that the pure colours appear close to the left side of the medial line where the vertices lie, and white in the space covered by them all, while the colours due to all possible different combinations of parcels of the prismatic rays, between the extreme red and violet, fill the intermediate space. The other half on the contrary is made up of the colours due to combinations of two parcels of rays reaching from the extreme rays to the intermediate parcel belonging to the corresponding part in the first half. The predominant colour within the left half of the lozenge is Green, and within the

right half, Pink. The colours on the edges are of course the same in each half, but reversed in position.



To see this splendid compendium of colours to advantage, and to study it as it deserves, the spectrum should be produced on a very large scale, by making the object very large, and viewing it from a distance proportionately great ; the White in the object should be as brilliant as possible, and the Black should be that of a dark cavity. With a little ingenuity it is possible to compare the colours of flowers, of pigments, or other brightly-coloured objects, with these combinations of the prismatic rays ; the coloured surface being placed in front of the prism so as to show against that part of the spectrum which most nearly resembles it. It is thus capable of being used as a natural standard or exemplar of colours, produceable with perfect truth in every place under the sun, and universally applicable, for every colour in nature must be some shade of a colour included in it.

CHAPTER III.

COMPLEMENTARY COLOURS.

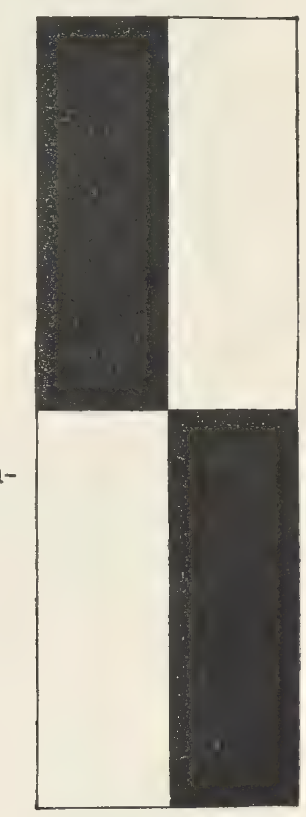
IF the rays of the Spectrum are collected in any two portions, the two resulting colours will be perfectly complementary to each other, the one containing both in hue and in brightness exactly what the other wants to make up the full White of the original light. Thus, the strongest Red which can be produced by combining the prismatic rays, is perfectly complementary to the strongest Seagreen; the strongest Green to the strongest Pink; and the strongest Blue to the strongest Yellow; and by the extreme application of the same principle, so also are Black and White.

The prismatic colours and their complementaries may be seen in opposition with each other by viewing through the prism a white line on a black ground, continuous with a black line of the same width on a white ground. In this beautiful and instructive experiment the observer who has not studied the subject before can hardly believe that the pale Seagreen and Yellow which he sees on one side should have power to neutralize (or turn into white) the deep Red and Blue which lie opposite to them. Yet that so it must be, is evident from the consideration that if the black line were filled up by the superposition of the white, that is, if the spectrum of the white line were superimposed on that of the black line, all the colours would merge into one uniform White.

If the white and black stripe is made of considerable width, then by holding the prism nearer and nearer to it, until White and Black appear in the middle of its spectrum, all the complementary combinations of the prismatic colours, exhibited at one view in the experiment mentioned in the last chapter, may be brought by turns into juxtaposition. But the strongest possible Red and Blue may be still more easily contrasted with their perfect complementaries by viewing through the prism an edge of white against black continuous with an edge of black against white; in which experiment Black, passing through the strongest Blue, Seagreen-blue, and Seagreen, into White, by the continued addition of all the prismatic rays beginning with the Violet, are beautifully opposed to White, passing through pale greenish Yellow, and

then the strongest Yellow, Orange, and Red, into Black, by the continued subtraction of the same rays.

To aid the performance of these experiments, which are of essential service for acquiring correct ideas of the prismatic colours and their complementaries, the following diagrams are given; and the names of the colours which will appear when they are viewed through a prism (the refracting edge pointing away from the spectator) are stated on each side.*



In the former of these experiments, when the prism is held at a certain distance from the object, the brightest or yellow part of the simple spectrum on the left-hand is seen to be equally luminous with the opposite darkest or blue part of the compound spectrum on the right-hand. Held nearer, this part of the simple spectrum becomes brighter, and the corresponding part of the other darker, and there appears on each side of it a place where the opposite colours are of equal brightness. In the latter experiment this is the case with one pair only of complementary colours—a Yellow-red and a Seagreen-blue; all the others exhibiting a contrast not in hue only, but in light and shade, or more accurately speaking, in White and Black, as well as in hue.

* For all such experiments as those recommended in this and the preceding chapter, it is a good plan to cut pieces in the form of the black parts out of a sheet of stiff white paper, and to view through the prism the remainder when strongly illuminated over a dark cavity; or still better, to cut pieces of the form of the white parts out of an opaque black screen, and use a bright white sky for the white.

Such observations as these are useful to aid the eye to distinguish colours that are complementary in hue, whether they differ in brightness or not.

All the pairs of complementary colours shewn in these experiments are alike in this, that the two added together not only completely neutralize each other, or destroy each other's hue, but also make the full White. Such pairs may be called perfect complementaries; and it is evident that for every possible colour such a perfect complementary is possible. But as one or both of such a pair of colours may be reduced in intensity, diluted with white or otherwise, without any alteration of hue, it is easy to see that there may be colours whose hues are in their kind complementary, although not equally powerful, so that the lights reflected from equal spaces of the two colours would not, if thrown together, fully neutralize each other; and also that if equally powerful, yet their lights added together may be lighter or darker than the full White.

When perfect complementaries are equally luminous, each colour is half as bright as the full White; and when one is darker than this, the other must be lighter in the same proportion.

CHAPTER IV.

INTERMEDIATE COLOURS.

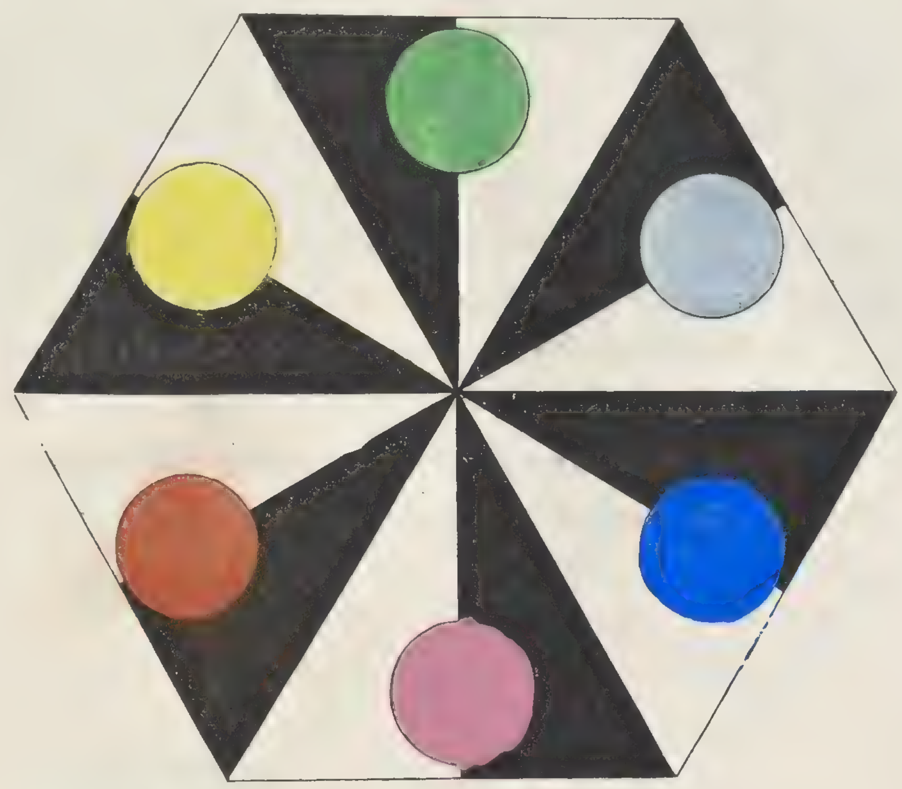
To determine correctly the colours which lie between two given colours is a most important point in the theory and practice of colours. There are two ways in which it may be readily effected:—

(1.) The two colours may be presented to the eye in the required proportions in such rapid succession that the one sensation does not vanish before the other is perceived. This is best done by causing the coloured surfaces to revolve on a circular disc, on which, by means of overlapping segments or other devices, any required combination may be effected. But unless mixtures of two colours in any given unequal quantities are wanted, this is not so convenient a method as the next.

(2.) Small equal spots of the colours to be mixed may be laid a little distance apart upon a neutral ground, equally illuminated; and a clean slip of thin polished glass being held vertically between them, the reflection of the one may be made to fall upon that part of the glass through which the other is seen. The more obliquely the light impinges on the glass, the more light is reflected and the less transmitted; so that by lowering the eye from a position high and near to the plane of the glass, to a position opposite to its lower part, every colour intermediate between the colours of the two spots may be seen.

To find the position of the eye in which the glass reflects and transmits the lights of the two coloured spots in equal proportions, a black and a white spot may be placed on alternate sides of each of the coloured spots; the required position will be that in which both of the opposite black and white spots are blended into the same Gray. In this way the true mean between any two colours may be easily found, and compared with any other colour, or with the mean between any two other colours. Thus the colours of Vermilion and Emerald Green compound an Olive-green, which is a shade of Yellow, not far from the mean between King's Yellow and Black: those of Emerald Green and Cobalt Blue, a dark Seagreen, not far from the mean between Verdigris and Black: those of Cobalt Blue and Vermilion, a Purple, not far from the

mean between Rose Madder and Black. The colours of Rose Madder and King's Yellow, again, compound a light Red, like that of Vermilion and White: those of King's Yellow and Verdigris, a light Green, like that of Emerald Green and White: those of Verdigris and Rose Madder, a light Blue, like that of Cobalt and White. Disregarding a little inequality in strength, the colours of Vermilion and Verdigris, those of Emerald Green and Rose Madder, and those of Cobalt Blue and King's Yellow, compound neutral Grays, not very far from the mean between Black and White, and are therefore tolerably good examples of complementary colours.



In the accompanying diagram spots of these colours are so arranged that by erecting the glass over the several diameters of the hexagon all their intermediate colours may be seen by turns; and the position of the eye in which the true mean in each case appears, is indicated by the reflected and transmitted White being equal on the right and left of the compound spot.*

If it be desired to see at once the whole gradation between two given colours, a stripe of each may be laid so as to cross at an acute angle, and the glass erected at the point of intersection.

In connexion with this head it should be noticed that a mixture of two pigments does not in general give a colour intermediate between their separate colours, unless all the rays given out by one of the two pigments are also given out by the other, as in the case of a white pigment being mixed with one of any colour, a yellow with a red or a green one, a pink with a red or a blue one, a seagreen with a green or a blue one, or lastly in the case of a pigment of any colour being mixed with a black one. For every pigment being more or less transparent, the kind of light which traverses both most freely is that which determines the resulting colour. Indigo, for instance, absorbs the red rays, but allows some of the green, together with the blue,

* A mixture of Emerald Green and Cobalt is used for the Seagreen, though inferior to Verdigris, the latter being extremely fugitive. To see the tints and shades of these colours, the glass should bisect the opposite black or white angles.

to traverse a very small depth of its substance; Gamboge absorbs the blue, but is permeable by the green and the red; little therefore beside the green rays can traverse both of these pigments together, and be reflected by the white paper underneath them to the eye, and the colour of their mixture is a dark Green, instead of a neutral Gray, which the mixture of their colours produces.

In other cases again the mixture of pigments may present a colour of the same hue with the true mixture of their colours, but darker. Thus by mixing Vermilion and Emerald Green, Emerald Green and Cobalt Blue, or Cobalt Blue and Vermilion, we may produce a series of Olive-greens, of Seagreens, or of Purples, but darker than those produced by the true mixture of the colours of those pigments. This is because each mixed pigment destroys some of the light which would otherwise be passed by the other. But the light-absorbing powers of the different pigments are so various that almost every mixture produces some peculiar divergence from the colours which form the direct gradation between the colours of the unmixed pigments, and it is evident therefore that any system of colours founded on the results of such mixtures must be fallacious.

When mixtures of three or more colours are required, rotation seems the only available method of determining their colours with accuracy.

CHAPTER V.

THE PRIMARY AND SECONDARY COLOURS.

The predominance of the three colours Red, Green, and Blue, which strikes the eye so powerfully in viewing the prismatic spectrum, arises from the circumstance that there is a greater depth of hue in the rays of those three colours than in any other. This has been proved by the careful experiments of Mr. Maxwell, recorded in the Transactions of the Royal Society for 1860, by which it appears that the colours of all the prismatic rays which lie between the deepest red and green rays may be produced by mixtures of those latter rays with very nearly the same depth of hue which they have in the spectrum; and that the like is true of the colours of the rays which lie between the deepest green and blue rays.

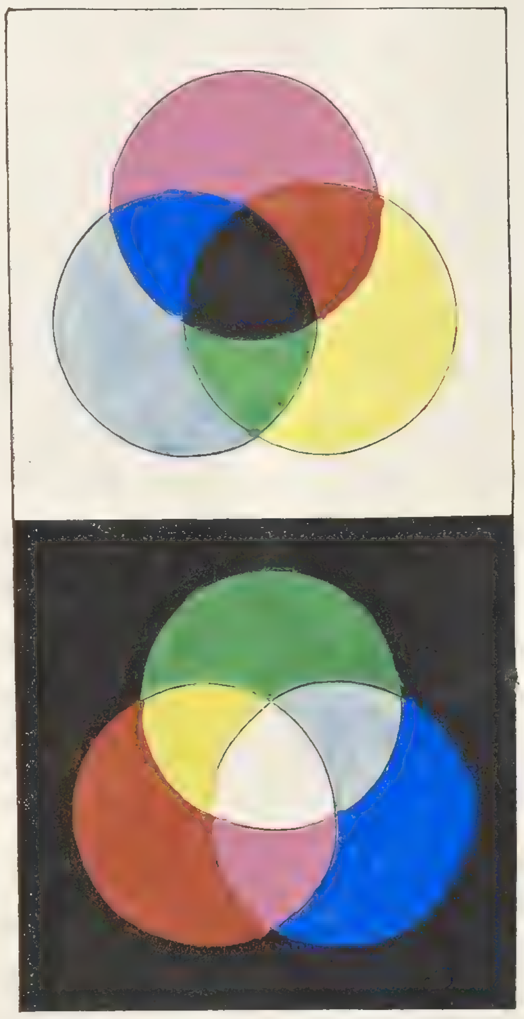
Hence there is little reason to doubt that these three are simple, elementary, or primary sensations of colour, and that the hues of all the intervening prismatic colours are compound, caused by some two of these sensations being excited at once in excess of the third. For nothing can be more probable than that each simple sensation is produced with greatest power by rays of some particular period of undulation, and with less and less power, the greater the difference of the period; and if so, it may well be supposed that those prismatic rays which have the greatest depth of colour, that is, the red, green, and blue rays, are those by which the simple sensations are severally most strongly excited, each in equal excess, or very nearly so, over the other two sensations.

It may be concluded, then, that the best Red, Green, and Blue, of the solar spectrum give the nearest possible approach to the three primary colours; and therefore that their complementary colours, Seagreen, Pink, and Yellow, give the nearest possible approach to those binary compounds of the primaries which are usually termed secondary colours. The brightness of each of these last (in its greatest intensity) must be equal to the sum of the brightnesses of the full intensities of their simple components. The Seagreen produced by the green rays added to the blue, must be as bright as the Green and Blue together; the Pink produced by the blue rays added to the red, must be as bright as the Blue and Red together; and the Yellow produced by the red rays added to the green, must be as bright as the Red

and Green together; White being of course as bright as the sum of the Red, Green, and Blue, which compound it.

These conclusions differ greatly from the theory which has for long been commonly assumed to be true, that Red, Yellow, and Blue, are the primary, and Orange, Green, and Purple, the Secondary colours. But that theory is entirely subverted not only by the researches above mentioned on the prismatic colours, but by all scientific experiments on the mixture of colours, which show that Red and Green, Yellow and Purple, Blue and Orange, are not complementary to each other.

In the accompanying diagram an attempt is made to represent, though very imperfectly, the true primary and secondary colours by the aid of those permanent pigments which seem most suitable.



The lower part of the diagram is intended to show the primary colours in equal strength, in three overlapping circles upon Black, forming the binary compounds where they overlap in pairs, and White where the three overlap. The upper part, on the contrary, exhibits the effect of taking away the same three simple colours from White, in three overlapping circles; leaving a secondary colour where one only is taken away, a primary colour where two are taken away, and Black where all are removed. If the representation were perfectly correct, the two parts would be perfectly complementary to each other, so that adding the light reflected from the one, to that reflected from the other, would reduce the whole to pure White; and mixing the one with the other would produce a uniform Gray, the mean between Black and full White.

The eight colours (using that term in its larger sense to include Black and White), which are intended to be represented in this diagram, may be termed the principal colours; and it may well be supposed that each of them would form as striking a contrast with its complementary, as full White does to Black, were it possible to present them to the eye with perfect purity: in practice, however, there is far more difference between Black and White than between the best Red and Seagreen, Green and Pink, or Blue and Yellow, that we can procure. The cause of this will be stated in the next chapter.

CHAPTER VI.

QUALITIES OF COLOURS.

BESIDES the brightness of a colour, which depends of course on the quantity of its light, and its richness (or strength of hue), which depends upon the quantity of the unneutralized part of its light, there are two qualities which have the greatest effect in striking the eye, and produce the manifest superiority of some colours over others. These are perhaps best expressed by the terms "depth" and "clearness."

The depth of a colour depends upon the ratio of its richness (as above defined) to its brightness. Perfection in this quality would require the absence from its composition of one at least of the three simple sensations. Thus the deeper a Black is, the less does it excite any of those sensations; the deeper a Red, a Green, or a Blue, the less does it excite two of them; and the deeper any colour whose hue is compounded of two of them, the less does it excite the remaining one, in proportion to the whole brightness of the colour.

The clearness of a colour, on the contrary, depends on the ratio of its richness to its darkness (that is, to its defect from the brightness of full White). Perfect clearness therefore would require the presence of at least one of the three simple sensations in its full intensity. Thus the clearer a White is, the more powerfully does it excite all the three sensations; the clearer a Seagreen, a Pink, or a Yellow, the more powerfully does it excite two of them; and the clearer any colour in which Red, Green, or Blue predominates, the more powerfully does it excite the one predominant sensation.

Darkness and brightness, as well as those terms by which the shades and tints of colours (or their mixtures with Black and White) may be more strictly expressed, are therefore quite distinct from depth and clearness.

The terms "purity" and "fulness" are often applied to colours to express indiscriminately their depth and clearness; but it is evident that they can apply strictly, the one only to colours perfect in depth, and the other only to colours perfect in clearness; and it will appear by what follows, that excepting Black and White, such perfect colours cannot be found.

Accurate experiments on the prismatic colours have shown that they are of very unequal depth. Some of the dark blue rays have power to neutralize the yellow of the brightest part of the spectrum, which is ten times as luminous; so that a very large proportion of the brightness of the latter must be regarded as due to White, even if the Blue of the former be perfectly pure, which there is no reason to believe, for in all probability none of the prismatic colours are perfectly pure, but every ray excites more or less all the three simple sensations.*

The deepest of all colours that are possible (next to Black itself), are the Violet and Blue of the more refrangible rays of the spectrum; the next are the Reds of the least refrangible, and the Purples, Dark Pinks, and Crimsons, produced by combining the rays of both ends of the spectrum. Next come the Greens of the best green rays, then the Seagreens, and lastly the Yellows, the least deep of all the prismatic colours. With respect to Blue and Red, and their compounds, the deepest colour must be dark; not having one sixth of the brightness of full White. With Green there is no difference in the possible depth up to a brightness of one half of that of full White; with Seagreen there is not much difference up to a brightness of two thirds, and none with Yellow up to a brightness of perhaps three fourths.

Whatever is true of any colours as to depth, must evidently be true of their perfect complementaries as to clearness; hence the Yellows are the clearest of all colours next to White; then the Seagreens, the Greens, the Pinks, the Reds, and lastly the Blues. Thus the best light Blues and Reds that can be obtained are no better than tints made by diluting the best dark Blues and Reds with White; while the best dark Yellows and Seagreens are but shades of the light ones. Greens and Pinks hold an intermediate rank in both these respects.

The colours of all natural bodies, though all more or less inferior in depth to those of combinations of continuous portions of the prismatic rays, agree generally in these properties. Among pigments the deepest are Blues, Reds, and their intermediate hues. and the deepest of these are dark, such as Intense Blue, Ultramarine, French Blue, Smalt, Carmine, and Crimson Lake. The clearest are Yellows, Seagreens, and Greens, and the clearest of these are light, as Lemon Yellow, King's Yellow, Verdigris, Emerald-Green; though there are also tolerably deep Greens, as that called Viridian, or Veronese Green, and clear Pinks, as Rose Madder. In light Blues we find nothing better than tints of Ultramarine or Cobalt; in dark Yellow hardly anything better than such Olive-greens as may be made by mixing Gamboge with Lampblack.

* See Helmholtz's Experiments on the Prismatic Colours, *Poggendorff's Annalen*, xciv., as well as Maxwell's above referred to; also Fraunhofer's curve of light intensity in the spectrum. From a careful comparison of the last two, the results stated in the next paragraph are derived.

These circumstances have led to the common opinion that Blue and Purple have the closest affinity to Black, Yellow and Green to White. They account for the fact that of all contrasts in hue between perfectly complementary colours, the strongest are those between dark Blues or Purples, and light Yellows or Greens; and the weakest are those between dark Yellows or Greens, and light Blues or Pinks; and also that complementary colours of about the middle degree of brightness form far weaker contrasts than do those which are nearer to Black with those that approach to White, and that the strongest of all contrasts is that between Black and White; not simply because there is the greatest difference in brightness between these two, but because Black can be obtained in greater depth, and White in greater clearness, than any other colour.

The preponderance of contrasts in Black and White, which hence arises, is so great that in a feeble light all distinction of colour is lost long before objects become invisible; and for the same reason intelligible representations can be made of almost all objects in light and shade alone, without any attempt to imitate their peculiar hues. The same circumstance is doubtless of great value in giving a measure of unity or simplicity of effect to every scene; and the endless variety of colour in nature becomes an embellishment which charms the eye without perceptibly hindering its appreciation of form.

It is a singular fact that the colour of a surface may vary in depth under different degrees of the same light. A red which in a bright light is brighter than a blue, in a dull light becomes darker; for while the former approaches rapidly to Black, the latter differs less and less from the appearance of White in diminishing light. Yet no change takes place in the hues, or in the relative strength of the hues of the colours of different surfaces, when the intensity of the light is changed; for their powers of mutual neutralization are unaltered, and a surface that is white in a dull light, continues so in a bright one. It would seem therefore that the red rays lose depth of colour when their intensity increases, their brightness increasing faster than their redness, as if by the addition of White; while the contrary effect takes place with the blue rays. These changes must arise from some difference in the action of strong and weak lights of the same kind on the retina; for they come without altering the illumination of the coloured surfaces, if the quantity of light admitted into the eye is altered, as by nearly closing the eyelids.

CHAPTER VII.

THE NATURAL SYSTEM OF COLOURS.

A SCHEME by which colours may be arranged according to their natural affinity, and their relationship exhibited by their places in a complete system, will be a useful aid in forming and retaining a correct idea of the whole assemblage of colours, and in devising new and beautiful arrangements.

The first attempt at such a scheme was made by the astronomer Mayer (1758). Supposing that all colours could be produced by mixtures of Red, Yellow, and Blue, he placed those three colours, with that degree of brightness in which they appear clearest, at the corners of an equilateral triangle, within which all their mixtures of equal brightness were disposed in order. The gradations between all these colours and Black and White fill two pyramids, whose apices are Black and White on the opposite sides of the triangle. In this way, with true primaries, all mixtures equalling a full primary in brightness might be correctly arranged, together with all their shades and tints; but no place is provided for the full secondaries, and many other combinations of greater brightness than a full primary.

Otto Runge, of Hamburgh (1810), proposed a colour-sphere; Black and White occupying the poles, Gray the centre, and Red, Orange, Yellow, Green, Blue, and Purple, six equidistant points on the equator. All the deepest colours would be found on the hemisphere whose pole was black, and all the clearest on the opposite hemisphere, and the gradations between these outer colours and Gray, in the respective radii. This system, though more complete than the former, is less correct in this respect, that many direct gradations, such as those between the full primaries and their adjacent secondaries, and between them and White and Black, would not be represented by straight lines; it also disregards the brightness of colours in placing the full primaries and secondaries at equal distances from Black and White.

Chevreul, in his well-known system, comprises the same colours, with less symmetry, in a hemisphere; his "Normal Colours," the best of each hue, forming the circumference, and White the centre. The shades or "higher tones" of the Normal Colours occupy the surface, up to Black at the summit; their tints or "lower tones," the base, and all other gradations to White, the radii.

But to apply the ordinary method of representing geometrically in their true relations all the combinations that can be formed out of three independent variable quantities, a point must be taken to represent zero or Black, the absence of all light,

and three lines drawn from it at right angles with each other, in which, and in all parallel co-ordinates, Red Green and Blue respectively must be supposed to increase in intensity from nothing upwards. Those intensities of Red Green and Blue which taken together constitute White must be supposed to be equal, and will be represented by equal distances in the three rectangular directions. The outer extremities of such three equal lines will therefore be the places of full Red, full Green, and full Blue, in some given intensity of White; and the lines themselves will contain the gradations from Black up to those three colours. If then the cube, of which the same lines would form three edges, be completed, it would obviously contain a place for every possible combination of Red Green and Blue, from Black, in which all three are *nil*, up to the White in which all three are of full intensity; and the number of distinct combinations would of course be the cube of whatever number of steps are taken from Black to a full primary, both included.

The corner of the cube opposite to Black would be full White: the corners opposite to Red, Green, and Blue, would be Seagreen, Pink, and Yellow. The central point would be a medium Gray. The three sides which adjoin to the corner of Black would respectively contain all those colours in which there is no Red, no Green, and no Blue; while the opposite three which adjoin to the corner of White, would contain all those which have full Red, full Green, and full Blue. Thus the six sides may be distinguished by the primary which is absent, or fully present, in each; and the twelve edges, being lines of which each is common to two sides, by the two primaries of which each contains nothing or all.

There are thirteen principal diameters or axes in the cube, and they may be divided into three classes. The three which join the middle points of the opposite sides may be called primary axes, because on them there is a change in one of the primaries only. The six which join the middle points of the opposite edges may be called secondary axes, because on them there is an equal change in two of the primaries, either in the same or in contrary directions. The four which join the opposite corners in like manner may be called tertiary axes, because there is an equal change of all the three primaries, either all in the same direction, or two in the same and one in the contrary direction. Those axes along which one colour diminishes while another increases in intensity, may be distinguished as cross axes. In like manner there are thirteen principal medial planes, being those which bisect the cube at right angles to the thirteen axes. The advantage of distinguishing these principal lines and planes in the cube of colours will soon be seen in the facility with which the principal gradations, contrasts, and harmonious arrangements of colour may, by means of them, be classified and remembered.

In the accompanying plate the primary axes and lines parallel to them are shown by full lines; the secondary axes and lines parallel to them, by broken lines; the tertiary axes by dotted lines. The arrow-heads indicate the directions in which the cube may be conceived to increase with an increase of light. The different sides, edges, and corners, with their connected axes and medial planes, are as follows:—

Z G B S, side of no Red;—R Y P W, side of full Red;
  s r^1, axis of Red;—r m^3 m^4 s^1, medial plane of Red.
Z B R P, side of no Green;—G S Y W, side of full Green;
  p g^1, axis of Green;—g m^2 m^5 p^1, medial plane of Green.
Z R G Y, side of no Blue;—B P S W, side of full Blue;
  y b^1, axis of Blue;—b m^1 m^6 y^1, medial plane of Blue.

Z R, edge of no Green and no Blue;—S W, edge of full Green and full Blue;
  r s^1, axis of Seagreen;—G Y B P, medial plane of the sum of Green and Blue.
Z G, edge of no Blue and no Red;—P W, edge of full Blue and full Red;
  g p^1, axis of Pink;—B S R Y, medial plane of the sum of Blue and Red.
Z B, edge of no Red and no Green;—Y W, edge of full Red and full Green;
  b y^1, axis of Yellow;—R P G S, medial plane of the sum of Red and Yellow.

G Y, edge of full Green and no Blue;—B P, edge of no Green and full Blue;
  m^4 m^3, cross axis of Green and Blue;—Z R S W, medial plane of the difference of Green and Blue.
B S, edge of full Blue and no Red;—R Y, edge of no Blue and full Red;
  m m^2, cross axis of Blue and Red;—Z G P W, medial plane of the difference of Blue and Red.
R P, edge of full Red and no Green;—G S, edge of no Red and full Green;
  m^1 m^6, cross axis of Red and Green;—Z B Y W, medial plane of the difference of Red and Green.

Z, corner of Black;—W, corner of White;—Z W, axis of White;
  m^1 m^2 m^4 m^6 m^5 m^3, medial plane of the sum of Red, Green, and Blue.

R, corner of Red;—S, corner of Seagreen;—R S, cross axis of Red and Seagreen;
  g b m^3 p^1 y^1 m^4, medial plane of the difference of Red and the sum of Green and Blue.
G, corner of Green;—P, corner of Pink;—G P, cross axis of Green and Pink;
  b r m^2 y^1 s^1 m^5, medial plane of the difference of Green and the sum of Blue and Red.
B, corner of Blue;—Y, corner of Yellow;—B Y, cross axis of Blue and Yellow;
  r g m^6 s^1 p^1 m^1, medial plane of the difference of Blue and the sum of Red and Green.

It has been shown in the preceding chapters that of the colours which belong to the surface of the complete cube, only Black and White are possible. We have not sufficient data for determining how near to the different parts of the surface our best colours may approach. The possible portion of the cube probably varies somewhat in form and relative magnitude when the full White differs in brightness, and in different states of the eye; but it always approaches the surface of the cube most nearly on the sides of no Green, and of full Green.

THE CUBE OF COLOURS

Z, *Black*.

r, *Dark Red*

g, " *Green*

b, " *Blue*.

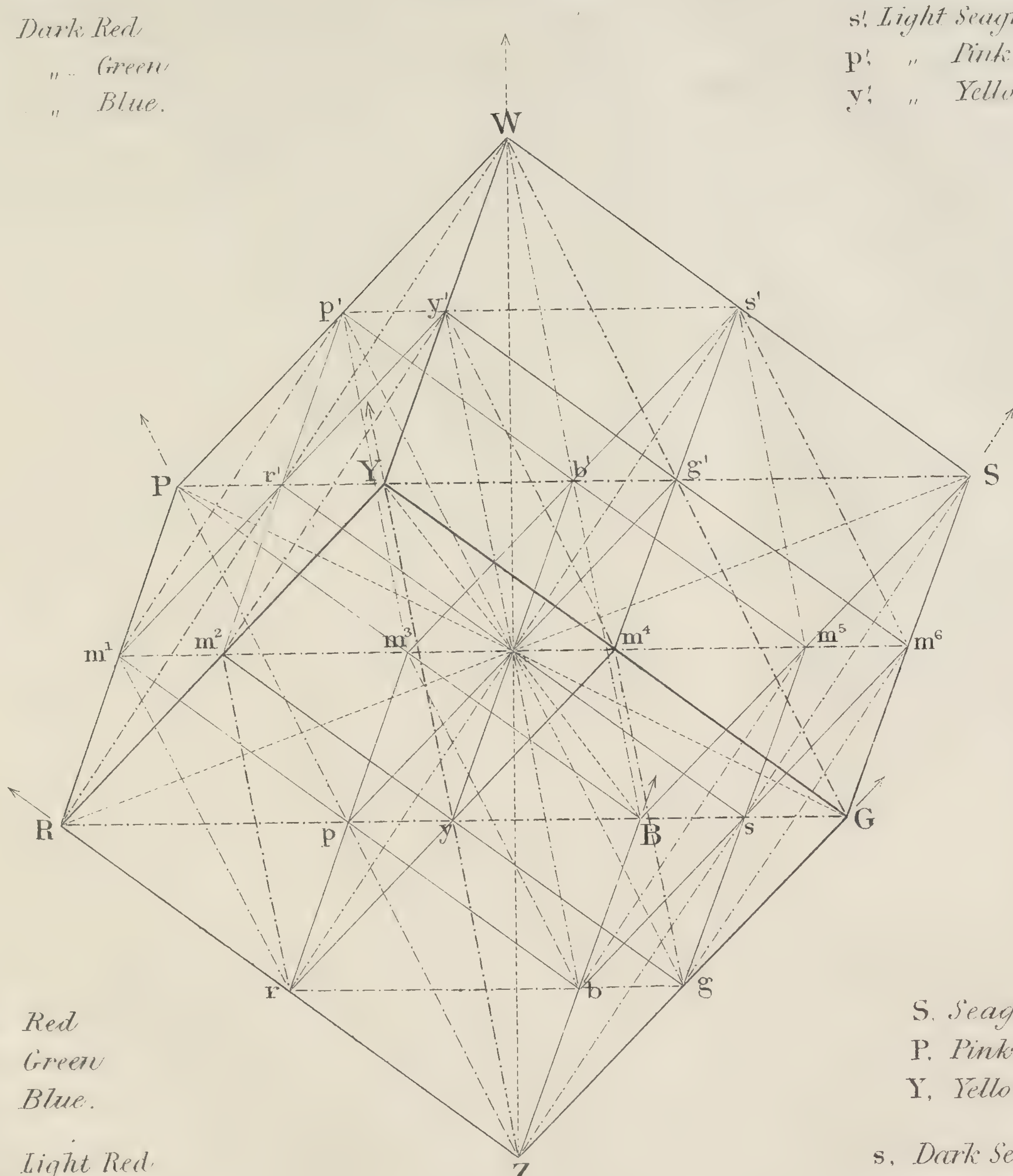
Centre, *Gray*.

W, *White*.

s', *Light Seagreen*

p', " *Pink*

y', " *Yellow*.



R, *Red*

G, *Green*

B, *Blue*.

r', *Light Red*

g', " *Green*

b', " *Blue*.

S, *Seagreen*

P, *Pink*

Y, *Yellow*.

s, *Dark Seagreen*

p, " *Pink*

y, " *Yellow*.

m¹, *Pink Red* m⁶, *Seagreen Green*

m², *Yellow Red* m⁵, *Seagreen Blue*

m⁴, *Yellow Green*. m³, *Pink Blue*.

J. W. Lowry sculp^t.

CHAPTER VIII.

GRADATIONS AND CONTRASTS OF COLOUR.

SINCE the quantity of Red, Green, and Blue, in the colour proper to any point in the cube of colours, is proportionate to the distance of that point from the sides of No Red, No Green, and No Blue, it follows that every straight line drawn through the cube passes through a uniform gradation of colour, the change in the quantity of each primary being equal at equal distances; also that all those gradations which are formed by the same changes, will be found in parallel lines. Thus, if we imagine lines drawn in every direction through every point in the cube, they will represent all possible gradations of colour; and these may be conveniently grouped in two ways:—

(1.) According to their direction; those parallel to the same line being taken together.

(2.) According to the point to which they converge; those converging to the same point being taken together.

Groups of the First Kind.

The leading parallel groups are those that are parallel to the axes of the cube. The principal gradations in each of these groups are given in the following lists, with the laws of their formation:—

Primary Gradations.

1. In the direction of the axis of Red, Red increases, without change in Green and Blue,

From	Black, ...	through	Dark Red, ...	to	Red.
,,	Dark Green, ...	,,	Dark Yellow, . . .	,,	Yellow-Red.
,,	Dark Blue, ...	,,	Dark Pink, ...	,,	Pink-Red.
,,	Green, ...	,,	Yellow-Green, . .	,,	Yellow.
,,	Dark Seagreen, . . .	,,	Gray, ...	,,	Light Red (axis).
,,	Blue, ...	,,	Pink Blue, ...	,,	Pink.
,,	Seagreen-Green, . . .	,,	Light Green, . . .	,,	Light Yellow.
,,	Seagreen-Blue, . . .	,,	Light Blue, ...	,,	Light Pink.
,,	Seagreen, ...	,,	Light Seagreen, . .	,,	White.

2. In the direction of the axis of Green, Green increases, without change in Blue and Red,

From	Black, ...	through	Dark Green, ...	to	Green.
„	Dark Blue, . . .	„	Dark Seagreen, . . .	„	Seagreen-Green.
„	Dark Red, . . .	„	Dark Yellow, ...	„	Yellow-Green.
„	Blue, ...	„	Seagreen-Blue, . . .	„	Seagreen.
„	Dark Pink, . .	„	Gray, ...	„	Light Green (axis).
„	Red, ...	„	Yellow-Red	„	Yellow.
„	Pink-Blue, . . .	„	Light Blue, ...	„	Light Seagreen.
„	Pink-Red, . . .	„	Light Red, ...	„	Light Yellow.
„	Pink, ...	„	Light Pink	„	White.

3. In the direction of the axis of Blue, Blue increases, without change in Red or Green,

From	Black, ...	through	Dark Blue, ...	to	Blue.
„	Dark Red, ...	„	Dark Pink, ...	„	Pink-Blue.
„	Dark Green, . . .	„	Dark Seagreen, . . .	„	Seagreen-Blue.
„	Red, ...	„	Pink-Red, ...	„	Pink.
„	Dark Yellow, . . .	„	Gray, ...	„	Light Blue (axis).
„	Green, ...	„	Seagreen-Green, . . .	„	Seagreen.
„	Yellow-Red, . . .	„	Light Red, ...	„	Light Pink.
„	Yellow-Green, . .	„	Light Green, ...	„	Light Seagreen.
„	Yellow, ...	„	Light Yellow, ...	„	White.

Secondary Gradations.

4. In the direction of the axis of Seagreen, Green and Blue increase equally, without change in Red,

From	Black, ...	through	Dark Seagreen, . . .	to	Seagreen.
„	Dark Red, . . .	„	Gray, ...	„	Light Seagreen (axis).
„	Red, ...	„	Light Red, ...	„	White.

Also from Dark Green . . . to Seagreen-Green.
„ Dark Blue . . . „ Seagreen-Blue.
„ Dark Yellow . . „ Light Green.

And from Dark Pink . . . to Light Blue.
„ Yellow-Red . . „ Light Yellow.
„ Pink-Red. . . . „ Light Pink.

5. In the direction of the axis of Pink, Blue and Red increase equally, without change in Green,

From	Black, ...	through	Dark Pink, . . .	to	Pink.
„	Dark Green, . . .	„	Gray, ...	„	Light Pink (axis).
„	Green, ...	„	Light Green, . .	„	White.

From Dark Blue . . . . . . to Pink-Blue.
„ Dark Red . . . . . . „ Pink-Red.
„ Dark Seagreen . . . „ Light Blue.

From Dark Yellow . . . . to Light Red.
„ Seagreen-Green . . „ Light Seagreen.
„ Yellow-Green . . . „ Light Yellow.

6. In the direction of the axis of Yellow, Red and Green increase equally, without change in Blue,

From Black . . . . . . through Dark Yellow, . . . to Yellow.
,, Dark Blue, . . . ,, Gray, ... ,, Light Yellow (axis).
,, Blue, ... ,, Light Blue, ... ,, White.

From Dark Red . . . . to Yellow-Red.	From Dark Seagreen . . . to Light Green.
,, Dark Green . . . ,, Yellow-Green.	,, Pink-Blue . . . . . . ,, Light Pink.
,, Dark Pink . . . ,, Light Red.	,, Seagreen-Blue . . . ,, Light Seagreen.

Secondary Cross Gradations.

7. In the direction of the cross axis of Green and Blue, Green increases and Blue decreases, equally, without change in Red,

From Blue, ... through Dark Seagreen, . . . to Green.
,, Pink-Blue, . . . ,, Gray, ... ,, Yellow-Green (axis).
,, Pink, ... ,, Light Red, ... ,, Yellow.

From Dark Blue. . . . . . to Dark Green.	From Light Blue . . . to Light Green.
,, Seagreen-Blue . . . ,, Seagreen-Green.	,, Pink-Red . . . . ,, Yellow-Red.
,, Dark Pink . . . . . ,, Dark Yellow.	,, Light Pink . . . ,, Light Yellow.

8. In the direction of the cross axis of Blue and Red, Blue increases and Red decreases, equally, without change in Green,

From Red, ... through Dark Pink, ... to Blue.
,, Yellow-Red, . . . ,, Gray, ... ,, Seagreen-Blue. (axis)
,, Yellow, ... ,, Light Green, ... ,, Seagreen.

From . . . Dark Red . . . . to . . . Dark Blue.	From Light Red . . . . . . to Light Blue.
,, . . . Pink-Red . . . . ,, . . , Pink-Blue.	,, Yellow-Green . . . ,, Seagreen-Green.
,, . . . Dark Yellow . . ,, . . . Dark Seagreen.	,, Light Yellow . . . . ,, Light Seagreen.

9. In the direction of the cross axis of Red and Green, Red increases and Green decreases, equally, without change in Blue,

From Green, ... through Dark Yellow, . . . to Red.
,, Seagreen-Green, . . . ,, Gray, ... ,, Pink-Red (axis).
,, Seagreen, ... ,, Light Blue, ... ,, Pink.

From Dark Green. . . . . to Dark Red.	From Light Green . . . . . to Light Red.
,, Yellow-Green . . . ,, Yellow-Red.	,, Seagreen-Blue . . . . ,, Pink-Blue.
,, Dark Seagreen . . . ,, Dark Pink.	,, Light Seagreen . . . ,, Light Pink.

Tertiary Gradation.

10. In the direction of the axis of White, Red and Green and Blue increase equally,

From Black, . . . through Gray, . . . to White (axis).

From Dark Red . . . . . to Light Red.	From Dark Seagreen . . . to Light Seagreen.
,, Dark Green . . . ,, Light Green.	,, Dark Pink . . . . . . ,, Light Pink.
,, Dark Blue . . . . ,, Light Blue.	,, Dark Yellow . . . . ,, Light Yellow.

Tertiary Cross Gradations.

11. In the direction of the cross axis of Red and Seagreen, Green and Blue increase, and Red decreases, equally,

From Red, . . . through Gray, . . . to Seagreen (axis).

From Dark Red . . . . to Dark Seagreen.	From Light Red . . . . . to Light Seagreen.
„ Yellow-Red . . . „ Light Green	„ Dark Yellow . . . „ Seagreen-Green.
„ Pink-Red . . . . „ Light Blue.	„ Dark Pink . . . . . „ Seagreen-Blue.

12. In the direction of the cross axis of Green and Pink, Blue and Red increase, and Green decreases, equally,

From Green, . . . through Gray, . . . to Pink (axis).

From Dark Green . . . . . to Dark Pink.	From Light Green . . . . . to Light Pink.
„ Yellow-Green . . . . „ Light Red.	„ Dark Seagreen . . . „ Pink-Blue.
„ Seagreen-Green. . . „ Light Blue.	„ Dark Yellow . . . . „ Pink-Red.

13. In the direction of the cross axis of Blue and Yellow, Red and Green increase, and Blue decreases, equally,

From Blue, . . . through Gray, . . . to Yellow (axis).

From Dark Blue . . . . . . to Dark Yellow.	From Light Blue . . . . . . to Light Yellow.
„ Pink-Blue . . . . . . „ Light Red.	„ Dark Pink . . . . . . „ Yellow-Red.
„ Seagreen-Blue . . . „ Light Green.	„ Dark Seagreen . . . „ Yellow-Green.

The mean colours in all the minor gradations may be easily found by reference to the figure of the cube. In those parallel to the tertiary axes they are all intermediate between the nearest corner colour, and the central Gray; and may be designated Dark Gray, Gray Red, Gray Green, Gray Blue, Gray Seagreen, Gray Pink, Gray Yellow, and Light Gray.

Groups of the Second Kind.

The leading convergent groups of gradations are those which tend towards the principal colours. The principal gradations in each of these are given the following lists, with the laws of their formation:—

1. In gradations tending to Black, Red and Green and Blue decrease in proportion to their respective quantities, as

From White	through Gray.	
„ Seagreen. . .	„	Dark Seagreen.
„ Pink	„	Dark Pink.
„ Yellow	„	Dark Yellow.
„ Red	„	Dark Red.
„ Green	„	Dark Green.
„ Blue	„	Dark Blue.

2. In gradations tending to White, Red and Green and Blue increase in proportion to their respective defects, as

From Black	through Gray.	
„ Red	„	Light Red.
„ Green	„	Light Green.
„ Blue	„	Light Blue.
„ Seagreen. . .	„	Light Seagreen.
„ Pink	„	Light Pink.
„ Yellow	„	Light Yellow.

3. In gradations tending to Red, Red increases in proportion to its defect, and Green and Blue decrease in proportion to their quantities, as

From	Seagreen . . .	through	Gray.
,,	Green	,,	Dark Yellow.
,,	White	,,	Light Red.
,,	Blue	,,	Light Pink.
,,	Pink	,,	Pink-Red.
,,	Black	,,	Dark Red.
,,	Yellow	,,	Yellow-Red.

4. In gradations tending to Seagreen, Blue and Green increase in proportion to their defects, and Red decreases in proportion to its quantity, as

From	Red	through	Gray.
,,	Pink	,,	Light Blue.
,,	Black	,,	Dark Seagreen.
,,	Yellow . . .	,,	Dark Green.
,,	Green	,,	Seagreen-Green.
,,	White	,,	Light Seagreen.
,,	Blue	,,	Seagreen-Blue.

5. In gradations tending to Green, Green increases in proportion to its defect, and Blue and Red decrease in proportion to their quantities, as

From	Pink	through	Gray.
,,	Blue	,,	Dark Seagreen.
,,	White	,,	Light Green.
,,	Red	,,	Dark Yellow.
,,	Yellow . . .	,,	Yellow-Green.
,,	Black	,,	Dark Green.
,,	Seagreen . .	,,	Seagreen-Green.

6. In gradations tending to Pink, Blue and Red increase in proportion to their defects, and Green decreases in proportion to its quantity, as

From	Green	through	Gray.
,,	Yellow	,,	Light Red.
,,	Black	,,	Dark Pink.
,,	Seagreen . . .	,,	Light Blue.
,,	Blue	,,	Pink-Blue.
,,	White	,,	Light Pink.
,,	Red	,,	Pink-Red.

7. In gradations tending to Blue, Blue increases in proportion to its defect, and Red and Green decrease in proportion to their quantities, as

From	Yellow	through	Gray.
,,	Red	,,	Dark Pink.
,,	White	,,	Light Blue.
,,	Green	,,	Dark Seagreen.
,,	Seagreen . . .	,,	Seagreen-Blue.
,,	Black	,,	Dark Blue.
,,	Pink	,,	Pink-Blue

8. In gradations tending to Yellow, Red and Green increase in proportion to their defects, and Blue decreases in proportion to its quantity, as

From	Blue	through	Gray.
,,	Seagreen . . .	,,	Light Green.
,,	Black	,,	Dark Yellow.
,,	Pink	,,	Light Red.
,,	Red	,,	Yellow-Red.
,,	White	,,	Light Yellow.
,,	Green	,,	Yellow Green.

Contrast is the effect of the difference between two colours. The nature of the contrast is determined by the direction of the line between the places of the colours in the cube, and its strength by the length of that line. All contrasts of colours on the same line, or on different lines parallel to the same, are of the same nature, only

varying in strength according to the distance between their places. They may therefore be grouped in the same ways as gradations; and the extreme colours of the principal gradations above-mentioned under all the leading groups of gradations, will serve as examples of the principal contrasts belonging to the corresponding groups of contrasts. Thus the colours of distant points in lines parallel to a primary axis form contrasts in Red, in Green, or in Blue ; parallel to a secondary axis, contrasts in Seagreen, in Pink, in Yellow, and cross contrasts in Green and Blue, in Blue and Red, and in Red and Green; parallel to a tertiary axis, contrasts in Black and White, and cross contrasts in Red and Seagreen, Green and Pink, Blue and Yellow. Colours belonging to opposite points on any two parallel sections of the cube will be contrasts of equal strength and of the same nature: those belonging to a sphere described about any point in the cube, will contrast equally, though all in different ways, with their central colours.

Plate II. contains four series of sections of the cube, taken through the principal and their intermediate colours (one hundred and twenty-five in all). The places of the former are indicated by dark circles; of the latter by light ones; and a double circle denotes the central Gray. Gradations parallel to any primary, secondary, or tertiary axis, are indicated by full, broken, or dotted lines. The series in Fig. 1 is at right angles with a primary axis, and therefore three distinct sets of this form may be made; that in Fig. 2 is at right angles with a secondary axis, and may therefore have six variations; that in Fig. 3 is at right angles with a tertiary axis, and may have four variations. Fig. 4 gives one of the innumerable series of sections which may be taken across other diameters; in its medial section lies a tertiary axis and one of the three secondary axes perpendicular to it, so that it may have twelve variations.

Representations of the principal colours and their means (twenty-seven in all), arranged as they would occur in sections at right angles with the several axes of the cube, are all that can be given here. They may serve to illustrate those gradations and contrasts which are formed in the directions of the axes, and also to give some idea of the beauty and variety of regular combinations of colour, each distinguished by its own peculiar effect. The characteristics of the several sections, together with the names of the colours represented in each, are stated in front of the representations. All the thirteen sets contain the same colours arranged in different ways; and by ascertaining which of the axes lie in the middle section of each set, it will be easy to see what groups of parallel gradations and contrasts that set presents. In every set the place of the perfect complementary of any colour will be found by drawing a line from the colour's place to the central Gray, and producing it to the same

Fig. 1.

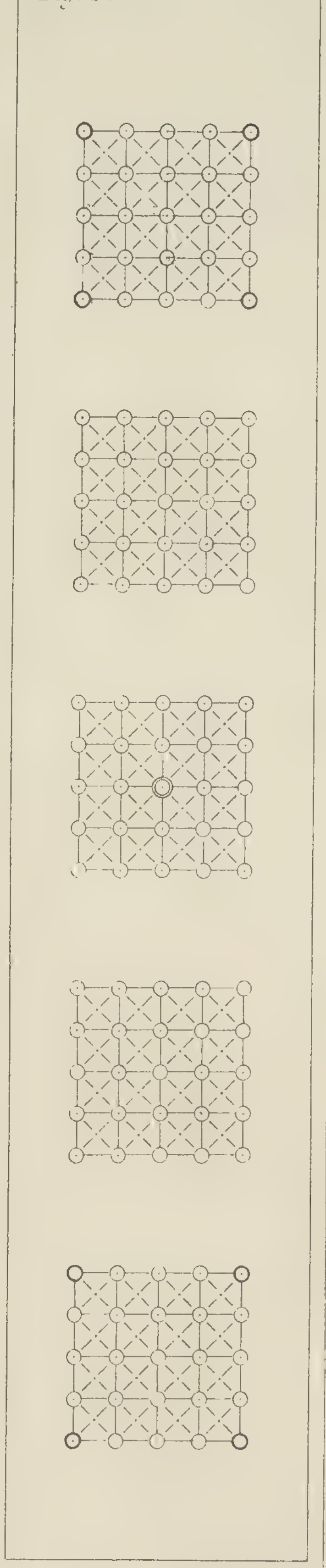


Fig. 2.

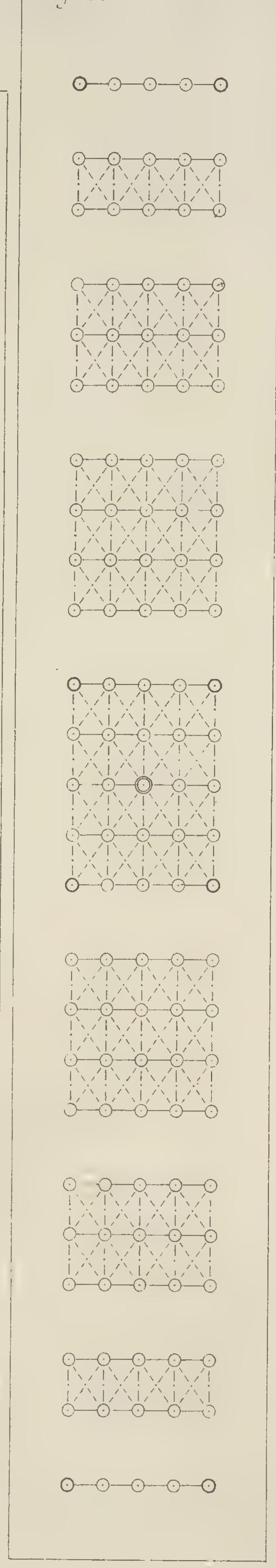


Fig. 3.

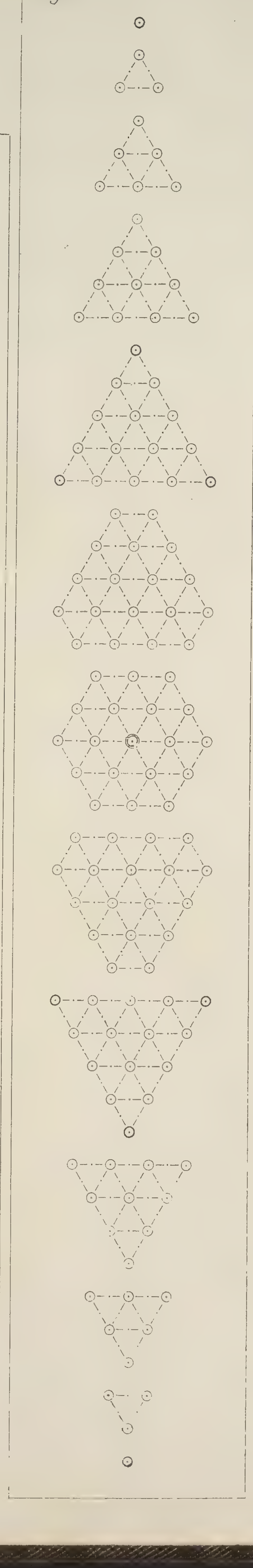
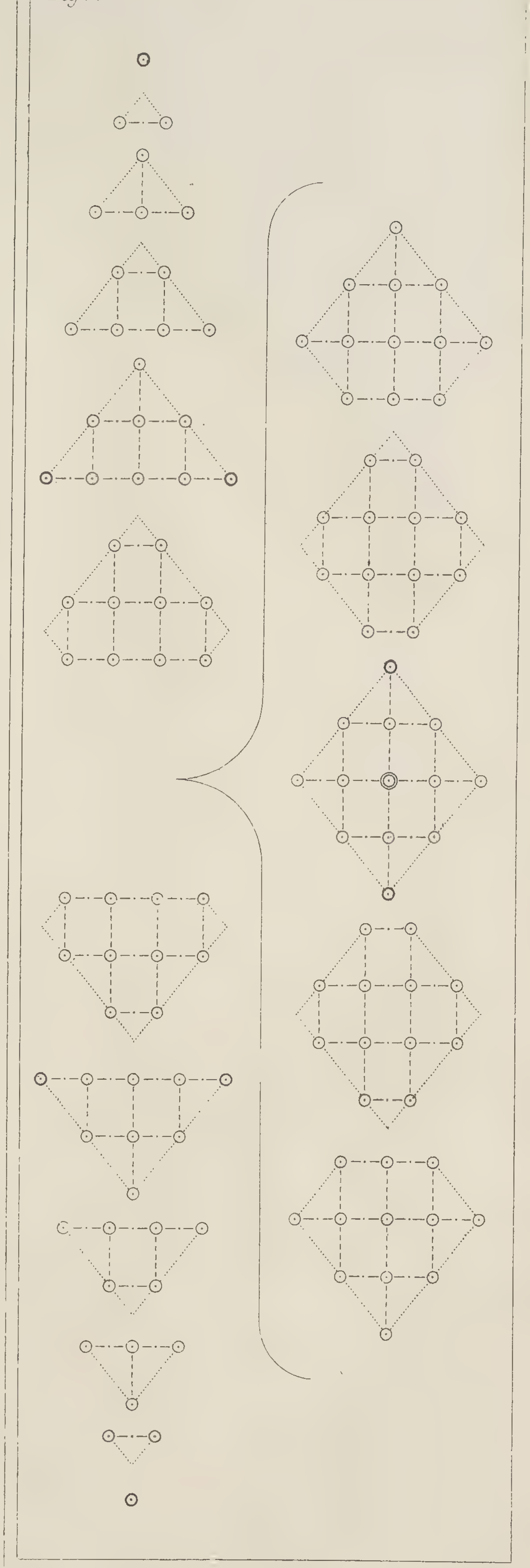


Fig. 4.



distance beyond. The colours of each section should produce if mixed its central colour. Those of each pair of sections equidistant from a medial section, as well as those in each whole set, should perfectly balance each other, producing, if mixed, the central Gray. Those of the three corresponding sections of any of the cognate sets should also neutralize each other.*

SECTIONS AT RIGHT ANGLES WITH THE PRIMARY AXES

OF RED (1).			OF GREEN (2).			OF BLUE (3).		
Colours containing full Red.			*Colours containing full Green.*			*Colours containing full Blue.*		
Yellow.	Light Yellow.	White.	Seagreen.	Light Seagreen.	White.	Pink.	Light Pink.	White.
Yellow-red.	Light Red.	Light Pink.	Seagreen-green.	Light Green.	Light Yellow.	Pink-blue.	Light Blue.	Light Seagreen
Red.	Pink-red.	Pink.	Green.	Yellow-green.	Yellow.	Blue.	Seagreen-blue.	Seagreen.
Colours containing half the full Red.			*Colours containing half the full Green.*			*Colours containing half the full Red.*		
Yellow-green.	Light Green.	Light Seagreen	Seagreen-blue.	Light Blue.	Light Pink.	Pink-red.	Light Red.	Light Yellow.
Dark Yellow.	Gray.	Light Blue.	Dark Seagreen.	Gray.	Light Red.	Dark Pink.	Gray.	Light Green.
Dark Red.	Dark Pink.	Pink-blue.	Dark Green.	Dark Yellow.	Yellow-red.	Dark Blue.	Dark Seagreen.	Seagreen-green.
Colours containing no Red.			*Colours containing no Green.*			*Colours containing no Blue.*		
Green.	Seagreen-green.	Seagreen.	Blue.	Pink-blue.	Pink.	Red.	Yellow-red.	Yellow.
Dark Green.	Dark Seagreen.	Seagreen-blue.	Dark Blue.	Dark Pink.	Pink-red.	Dark Red.	Dark Yellow.	Yellow-green.
Black.	Dark Blue.	Blue.	Black.	Dark Red.	Red.	Black.	Dark Green.	Green.

* The representations of the first twelve sets of sections have been prepared alternatively on a white or a black ground: the colours generally show better on the latter, but the effect of the gradations to Black is in great measure lost, and on the whole it is questionable which should be preferred. For the use of those readers who may wish to improve these necessarily imperfect imitations, a list of the pigments which have appeared most eligible is given in connexion with the thirteenth set. It need hardly be mentioned that they should be viewed in pure white light (that of a clear day when the sun is high), an excess of any hue in the incident light altering the colours of the pigments, and destroying their balance. The effect of any single section, or combination of corresponding sections, is best observed when the rest are covered.

SECTIONS AT RIGHT ANGLES WITH THE SECONDARY AXES

OF SEAGREEN (4).

Colours containing full Green and full Blue.

Seagreen.	Light Seagreen.	White.

Colours containing three-fourths the sum of full Green and Blue.

Seagreen-green.	Light Green.	Light Yellow.
Seagreen-blue.	Light Blue.	Light Pink.

Colours containing one-half the sum of full Green and Blue.

Green.	Yellow-green.	Yellow.
Dark Seagreen.	Gray.	Light Red.
Blue.	Pink-blue.	Pink.

Colours containing one-fourth the sum of full Green and Blue.

Dark Green.	Dark Yellow.	Yellow-red.
Dark Blue.	Dark Pink.	Pink-red.

Colours containing neither Green nor Blue.

Black.	Dark Red.	Red.

OF PINK (5).

Colours containing full Blue and full Red.

Pink.	Light Pink.	White.

Colours containing three-fourths the sum of full Blue and Red.

Pink-blue.	Light Blue.	Light Seagreen.
Pink-red.	Light Red.	Light Yellow.

Colours containing one-half the sum of full Blue and Red.

Blue.	Seagreen-blue.	Seagreen.
Dark Pink.	Gray.	Light Yellow.
Red.	Yellow-red.	Yellow.

Colours containing one-fourth the sum of full Blue and Red.

Dark Blue.	Dark Seagreen.	Seagreen-green.
Dark Red.	Dark Yellow.	Yellow-green.

Colours containing neither Blue nor Red.

Black.	Dark Green.	Green.

OF YELLOW (6).

Colours containing full Red and full Green.

Yellow.	Light Yellow.	White.

Colours containing three-fourths the sum of full Red and Green.

Yellow-red.	Light Red.	Light Pink.
Yellow-green.	Light Green.	Light Seagreen.

Colours containing one-half the sum of full Red and Green.

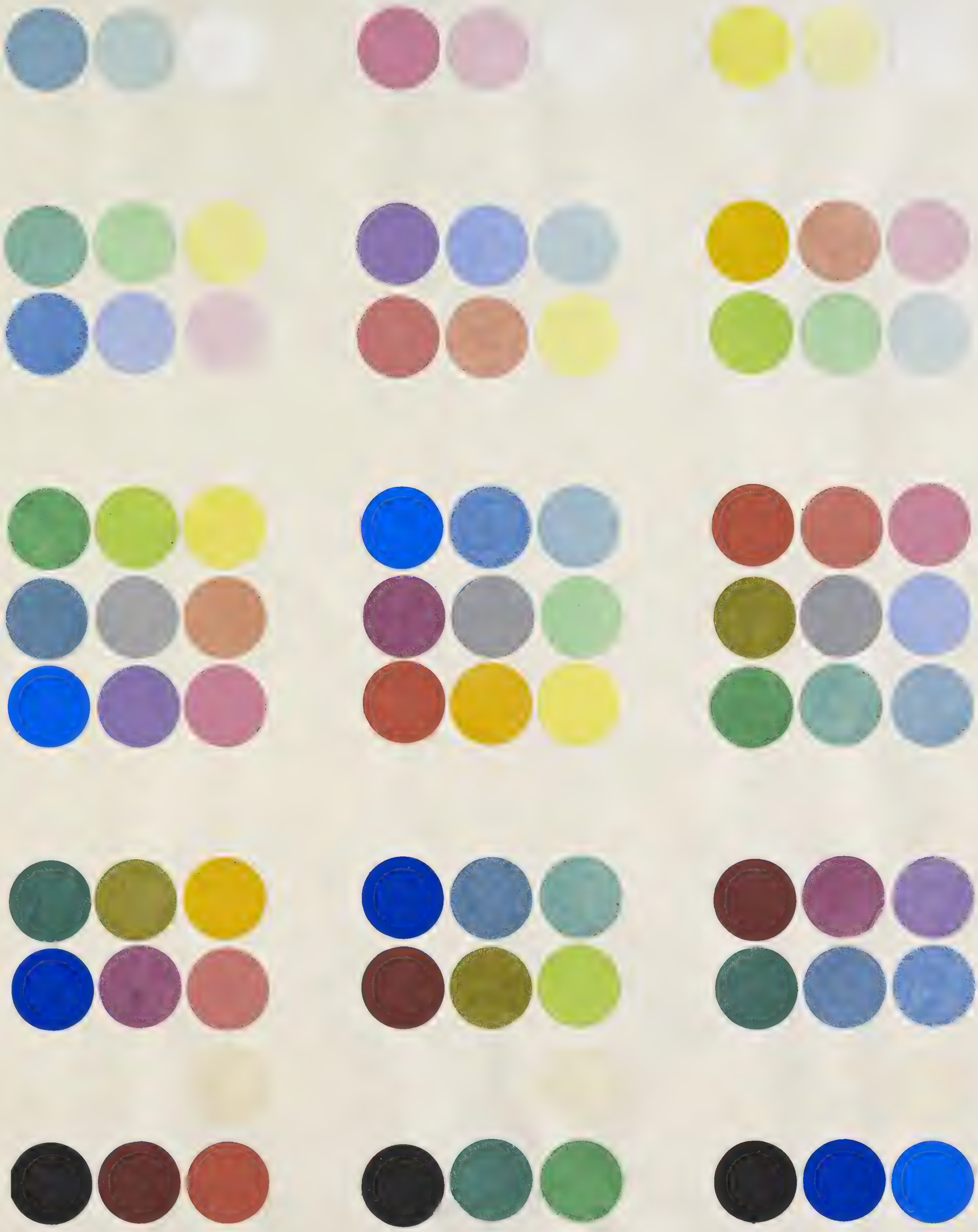
Red	Pink-red.	Pink.
Dark Yellow.	Gray.	Light Blue.
Green.	Seagreen-green.	Seagreen.

Colours containing one-fourth the sum of full Red and Green.

Dark Red.	Dark Pink.	Pink-blue.
Dark Green.	Dark Seagreen.	Seagreen-blue

Colours containing neither Red nor Green.

Black.	Dark Blue.	Blue.



SECTIONS AT RIGHT ANGLES WITH THE SECONDARY CROSS AXES

OF GREEN AND BLUE (7).	OF BLUE AND RED (8).	OF RED AND GREEN (9).
Colours containing full Green and no Blue.	*Colours containing full Blue and no Red*	*Colours containing full Red and no Green.*
Green. Yellow-green. Yellow.	Blue. Seagreen-blue. Seagreen.	Red. Pink-red. Pink.
Colours containing half the full Green in excess of Blue.	*Colours containing half the full Blue in excess of Red.*	*Colours containing half the full Red in excess of Green.*
Seagreen-green. Light Green. Light Yellow.	Pink-blue. Light Blue. Light Seagreen.	Yellow-red. Light Red. Light Pink.
Dark Green. Dark Yellow. Yellow-red.	Dark Blue. Dark Seagreen. Seagreen-green.	Dark Red. Dark Pink. Pink-blue.
Colours containing equal quantities of Green and Blue	*Colours containing equal quantities of Blue and Red.*	*Colours containing equal quantities of Red and Green.*
Seagreen. Light Seagreen. White.	Pink. Light Pink. White.	Yellow. Light Yellow. White.
Dark Seagreen. Gray. Light Red.	Dark Pink. Gray. Light Green.	Dark Yellow. Gray. Light Blue.
Black. Dark Red. Red.	Black. Dark Green. Green.	Black. Dark Blue. Blue.
Colours containing half the full Blue in excess of Green.	*Colours containing half the full Red in excess of Blue.*	*Colours containing half the full Green in excess of Red.*
Seagreen-blue. Light Blue. Light Red.	Pink-red. Light Red. Light Yellow.	Yellow-green. Light Green. Light Seagreen.
Dark Blue. Dark Pink. Pink-red.	Dark Red. Dark Yellow. Yellow-green.	Dark Green. Dark Seagreen. Seagreen-blue.
Colours containing full Blue and no Green.	*Colours containing full Red and no Blue.*	*Colours containing full Green and no Red.*
Blue. Pink-blue. Pink.	Red. Yellow-red. Yellow.	Green. Seagreen-green. Seagreen.

SECTIONS AT RIGHT ANGLES WITH THE TERTIARY CROSS AXES

OF RED AND SEAGREEN (10).	OF GREEN AND PINK (11).	OF BLUE AND YELLOW (12).
Colour containing full Green and Blue, and no Red Seagreen.	*Colour containing full Blue and Red, and no Green.* Pink.	*Colour containing full Red and Green, and no Blue.* Yellow.
Colours containing three-fourths the sum of full Green and Blue in excess of Red. Light Seagreen. Seagreen-blue. Seagreen-green.	*Colours containing three-fourths the sum of full Blue and Red in excess of Green.* Light Pink. Pink-red. Pink-blue.	*Colours containing three-fourths the sum of full Red and Green in excess of Blue.* Light Yellow. Yellow-green. Yellow-red.
Colours containing half the sum of full Green and Blue in excess of Red. White. Light Blue. Light Green. Blue. Dark Seagreen. Green.	*Colours containing half the sum of full Blue and Red in excess of Green.* White. Light Red. Light Blue. Red. Dark Pink. Blue.	*Colours containing half the sum of full Red and Green in excess of Blue.* White. Light Green. Light Red. Green. Dark Yellow. Red.
Colours containing one-fourth the sum of Green and Blue in excess of Red. Light Pink. Light Yellow. Blue-pink. Gray. Light Green. Dark Blue. Dark Green.	*Colours containing one-fourth the sum of full Blue and Red in excess of Green.* Light Yellow. Light Seagreen. Yellow-red. Gray. Seagreen-blue. Dark Red. Dark-blue.	*Colours containing one-fourth the sum of full Red and Green in excess of Blue.* Light Seagreen. Light Pink. Seagreen-green. Gray. Pink-red. Dark Green. Dark Red.
Colours containing equal quantities of Red and of the sum of Green and Blue. Pink. Light Red. Yellow. Dark Pink. Dark Yellow. Black.	*Colours containing equal quantities of Green, and of the sum of Blue and Red.* Yellow. Light Green. Seagreen. Dark Yellow. Dark Seagreen. Black.	*Colours containing equal quantities of Blue, and of the sum of Red and Green.* Seagreen. Light Blue. Pink. Dark Seagreen. Dark Pink. Black.
Colours containing one half of full Red in excess of the sum of Green and Blue. Pink-red. Yellow-red. Dark Red.	*Colours containing one half of full Green, in excess of the sum of Blue and Red.* Yellow-green. Seagreen-green. Dark Green.	*Colours containing one half of full Blue, in excess of the sum of Red and Green.* Seagreen-blue. Pink-blue. Dark Blue.
Colour containing full Red and neither Green nor Blue. Red.	*Colour containing full Green and neither Blue nor Red.* Green.	*Colour containing full Blue and neither Red nor Green.* Blue.

SECTIONS AT RIGHT ANGLES WITH THE TERTIARY AXIS OF WHITE.

(13).

The following pigments, sufficiently permanent for ordinary use, seem to give the nearest approach to the colours to which corresponding numbers are prefixed in Table 13, and have been used in this work to represent them.

Colour containing full Red, Green, and Blue.	
1. White.	1. Chinese White or Constant White.
Colours containing five-sixths of the sum of full Red, Green, and Blue.	
2. Light Pink.	2. Rose Madder powder (light).
3. Light Seagreen.	3. Ceruleum with a little Viridian (very light).
4. Light Yellow.	4. Lemon Yellow or King's Yellow (light).
Colours containing two-thirds of the sum of full Red, Green, and Blue.	
5. Pink.	5. Rose Madder powder (full).
6. Light Blue.	6. Cobalt powder (light).
7. Light Red.	7. Vermilion (light).
8. Seagreen.	8. Ceruleum with a little Viridian (light).
9. Light Green.	9. Emerald Green (rather light).
10. Yellow.	10. King's Yellow (full).
Colours containing half the sum of full Red, Green, and Blue.	
11. Pink-blue.	11. Rose Madder powder with Smalt.
12. Pink-red.	12 Carmine (rather light).
13. Seagreen-blue.	13. Ceruleum or Azure.
14. Gray.	14. Blacklead with White.
15. Yellow-red.	15. Cadmium, palest hue.
16. Seagreen-green.	16. Emerald Green with Ceruleum.
17. Yellow-green.	17. Permanent Yellow with Emerald Green.
Colours containing one-third of the sum of full Red, Green, and Blue.	
18. Blue.	18. Cobalt powder (full).
19. Dark Pink.	19. Crimson-lake with a little Smalt.
20. Red.	20. Vermilion (full).
21. Dark Seagreen.	21. Ceruleum with Viridian
22. Dark Yellow.	22. Olive Green.
23. Green.	23. Emerald Green (full).
Colours containing one-sixth of the sum of full Red, Green, and Blue.	
24. Dark Blue.	24. French Blue.
25. Dark Red.	25. Indian Lake.
26. Dark Green.	26. Viridian or Veronese Green.
Colour containing no Red, Green, or Blue.	
27. Black.	27. Lampblack (full).

The following Plates show methods of combining portions of the sections in Plate II., which may suggest innumerable other ways of grouping colours, according to their natural affinities; and any such group may be readily contrasted with its complementary group, or with its cognate groups.

Plate III. gives projections of the layers receding from an edge or a corner of the cube. In Fig. 5 the series begins at one of the twelve edges, and ends at the two opposite sides; there may therefore be twelve variations of this form. In Fig. 6 it begins at one of the eight corners, and ends at the three sides opposite; and there may be eight variations, of which the simplest is that commencing with Black, since the colours of the several layers in that case differ in intensity only. In Fig. 7 the series begins again at one of the corners, but ends at the three opposite edges. This kind also may therefore have eight variations.

Plate IV. gives developements of equidistant layers about the centre of the cube, taken at right angles in Fig. 8 to the primary, in Fig. 9 to the secondary, and in Fig. 10 to the tertiary axes. Every colour in each of these developements is accompanied with its perfect complementary. All of them may be varied in many ways by choosing different points for the middle of the developement

Plates V. and VI. give developements of the layers surrounding the axes of the cube. The layers are developed about a primary axis, parallel to two primary medial planes, in Fig. 11; to two secondary medial planes in Fig. 12. They are developed about a secondary axis, parallel to one primary and one secondary medial plane, in Fig. 13; parallel to two tertiary medial planes in Fig. 14. They are developed about a tertiary axis, parallel to three secondary medial planes in Fig. 15, and parallel to three of the medial planes of the fourth series of sections shown in Plate II., in Fig. 16. The diagrams at the foot of Plate VI. give plans of the layers developed in Figs. 11 to 16. Of the first and second kinds three variations may be made; of the third and fourth, six; of the remaining two, four. Each presents a set of gradations of the same class with that in its axis. The most interesting is perhaps that which is formed about the axis of White, in the way indicated in Fig. 15; the colours increasing in strength of hue in each successive layer.*

* The subject of this chapter has been thus largely elaborated, in the hope that the classification of gradations, contrasts, and natural combinations of colours, may be of practical use in ornamental art, and perhaps lead to improved principles of design.

Fig. 7.

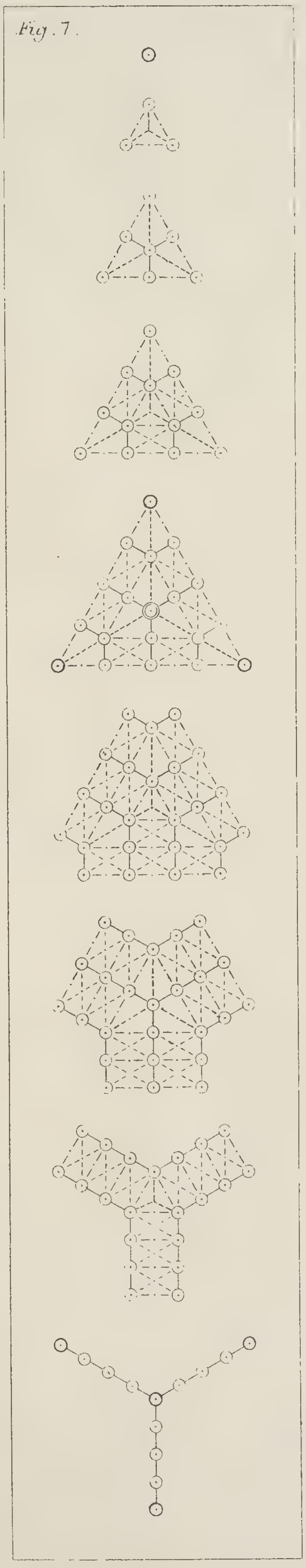


Fig. 5.

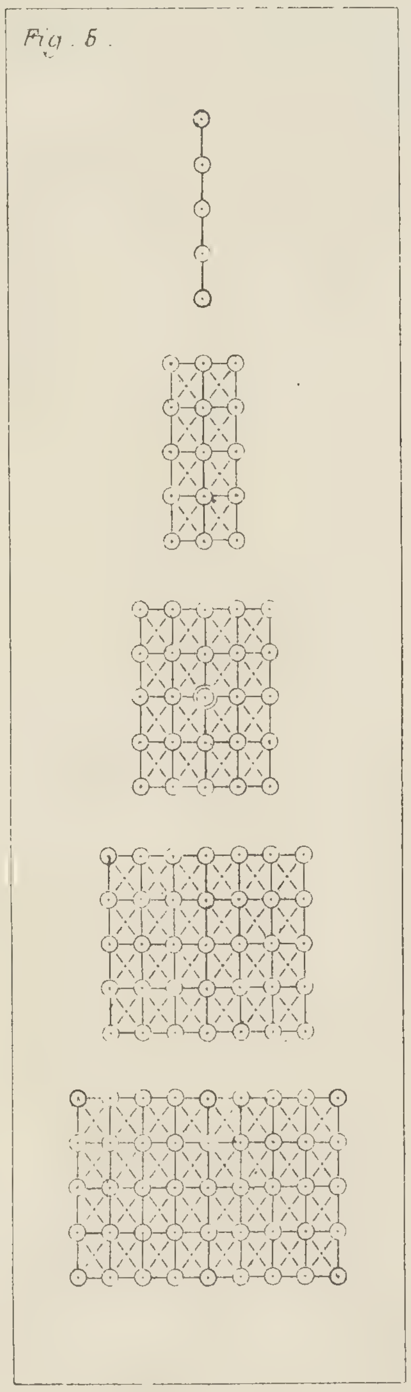


Fig. 6.

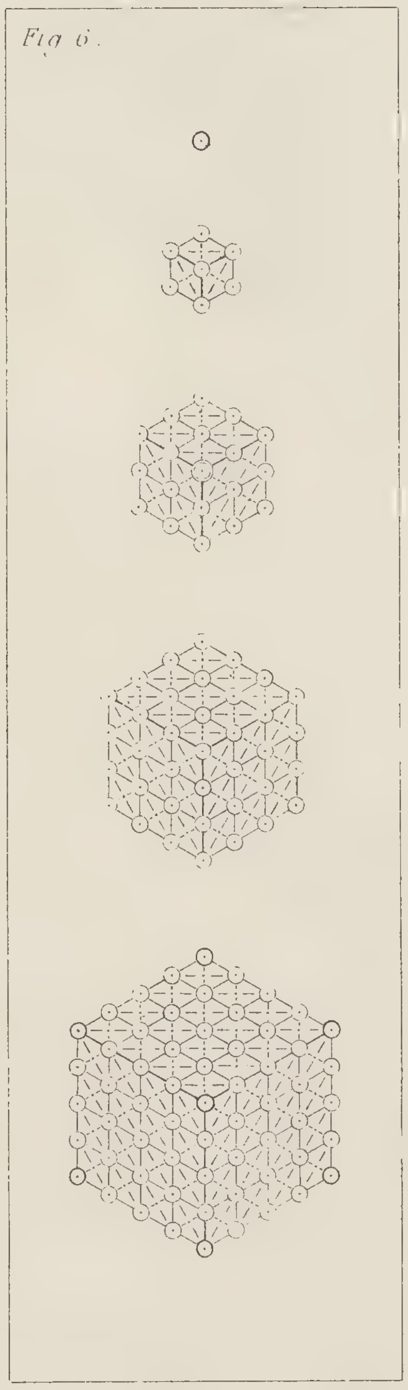


Fig. 8.

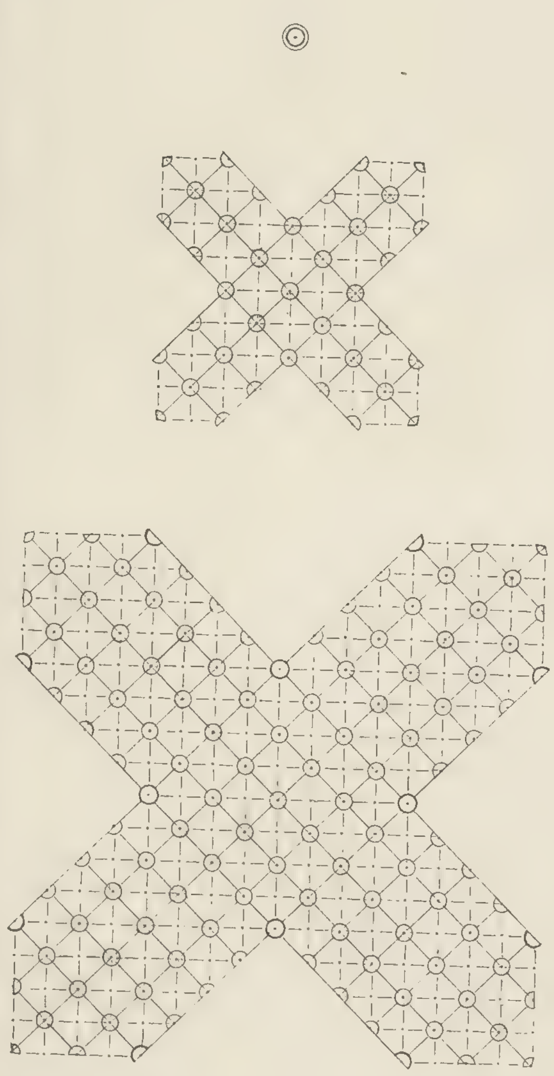


Fig. 10.

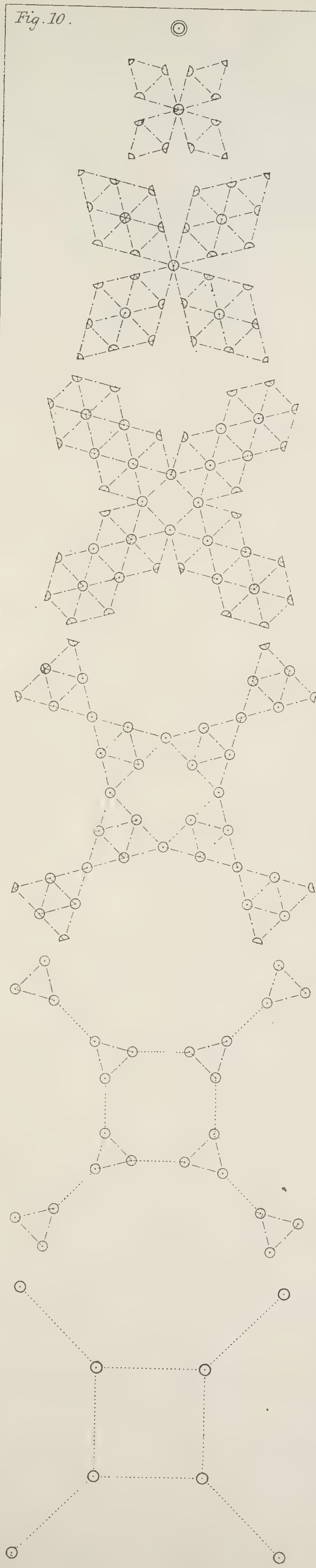


Fig. 9.

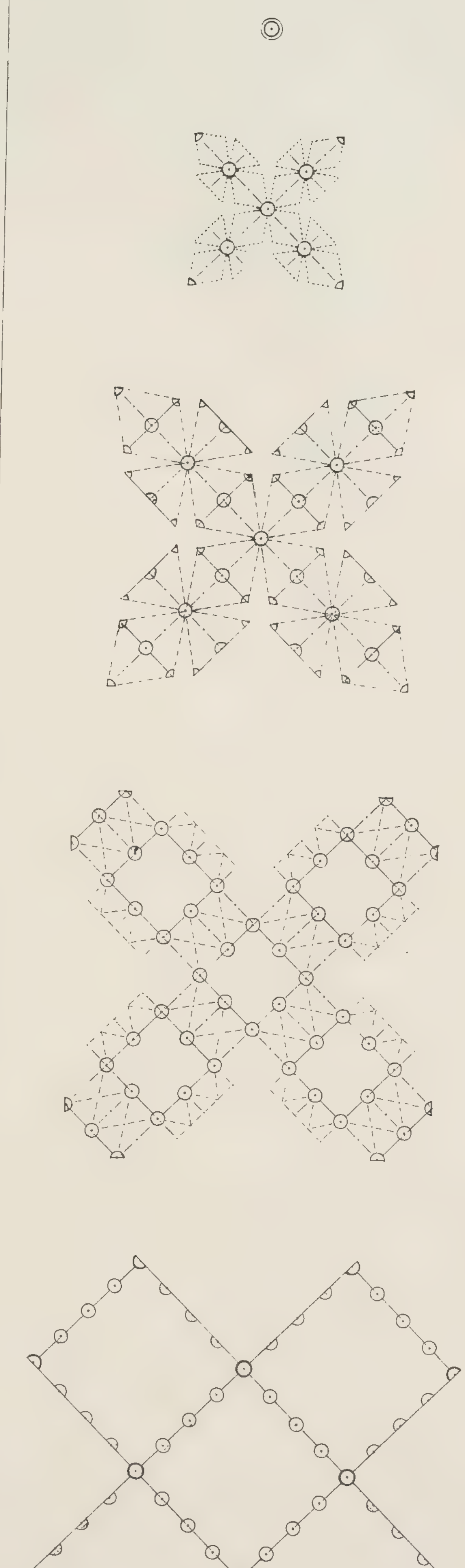


Fig. 11.

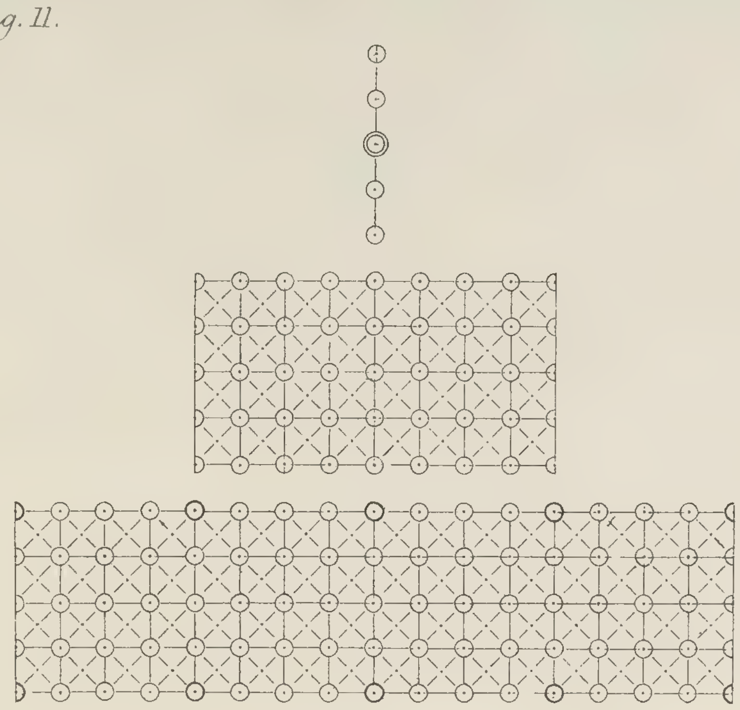


Fig. 12.

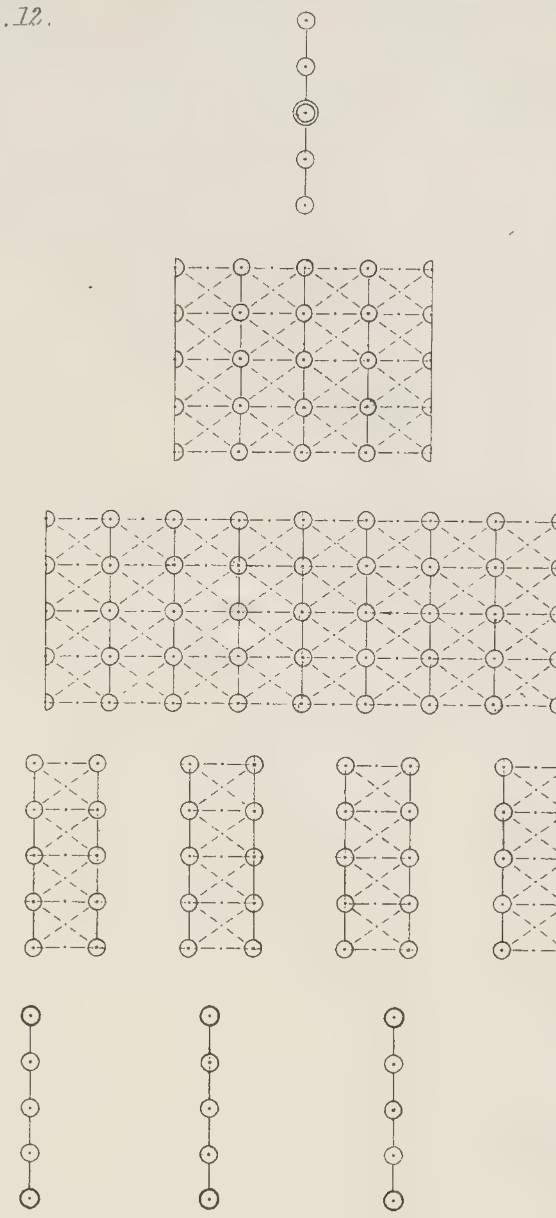


Fig. 14.

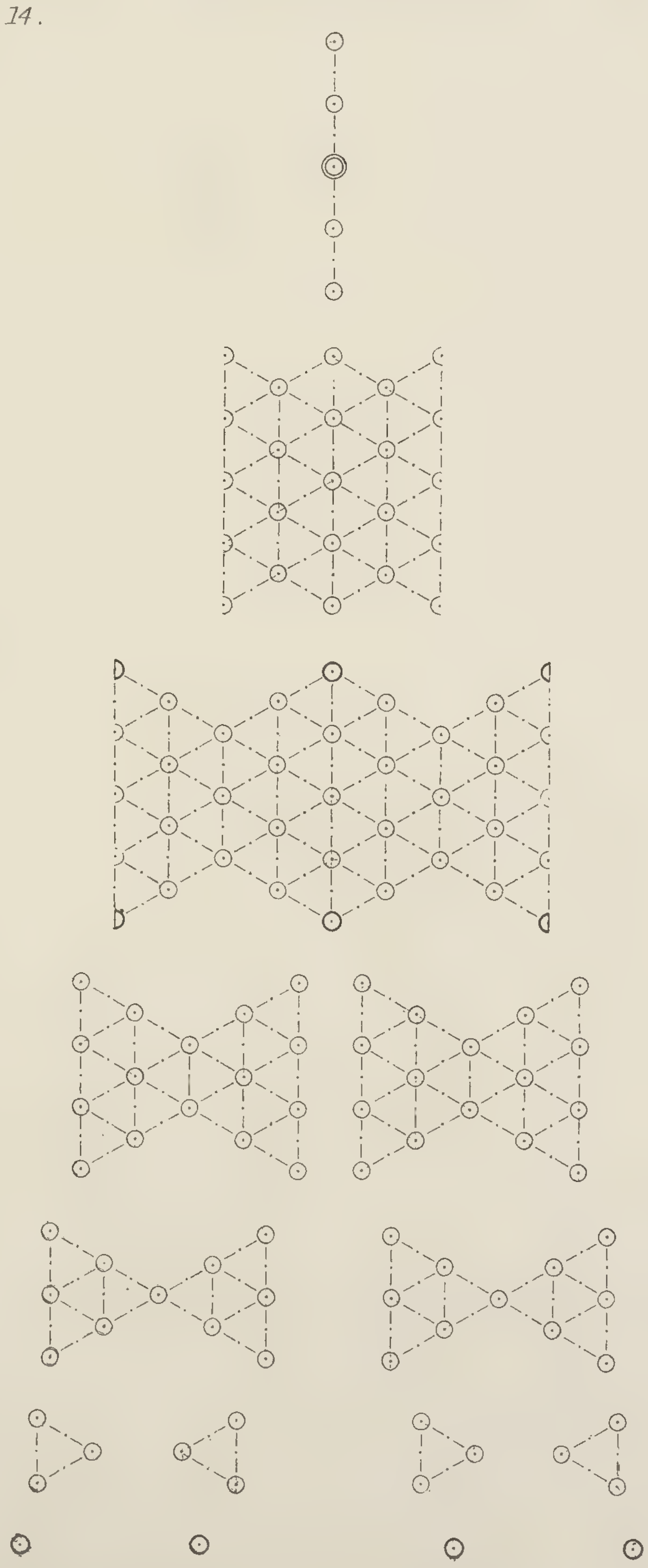


Fig. 13.

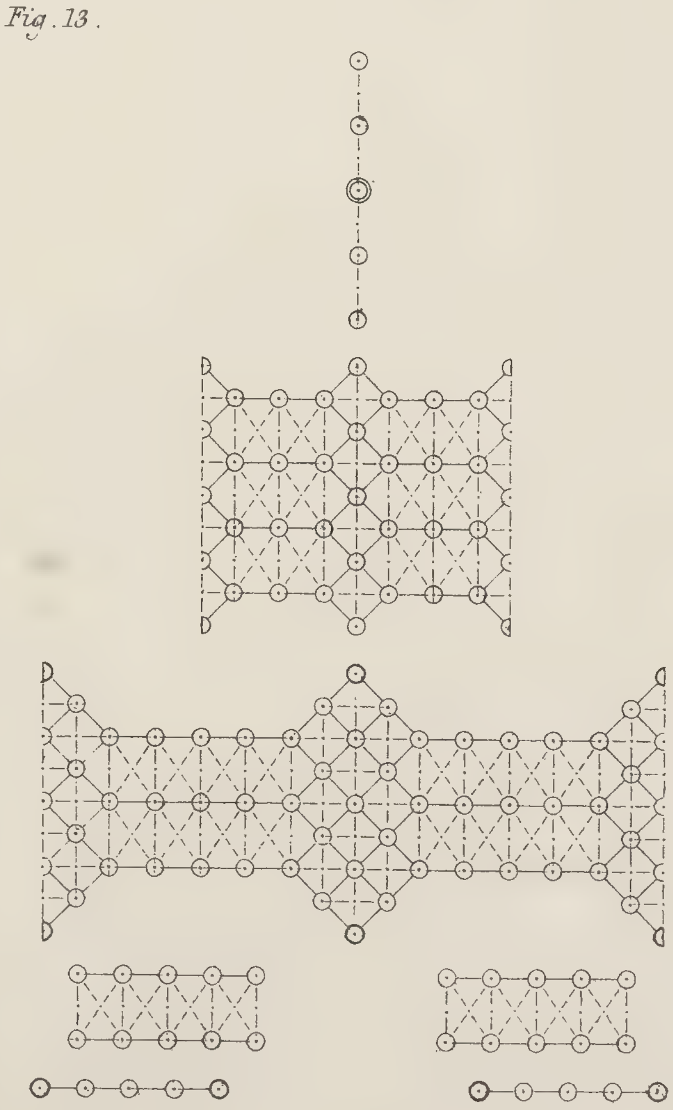


Fig. 15.

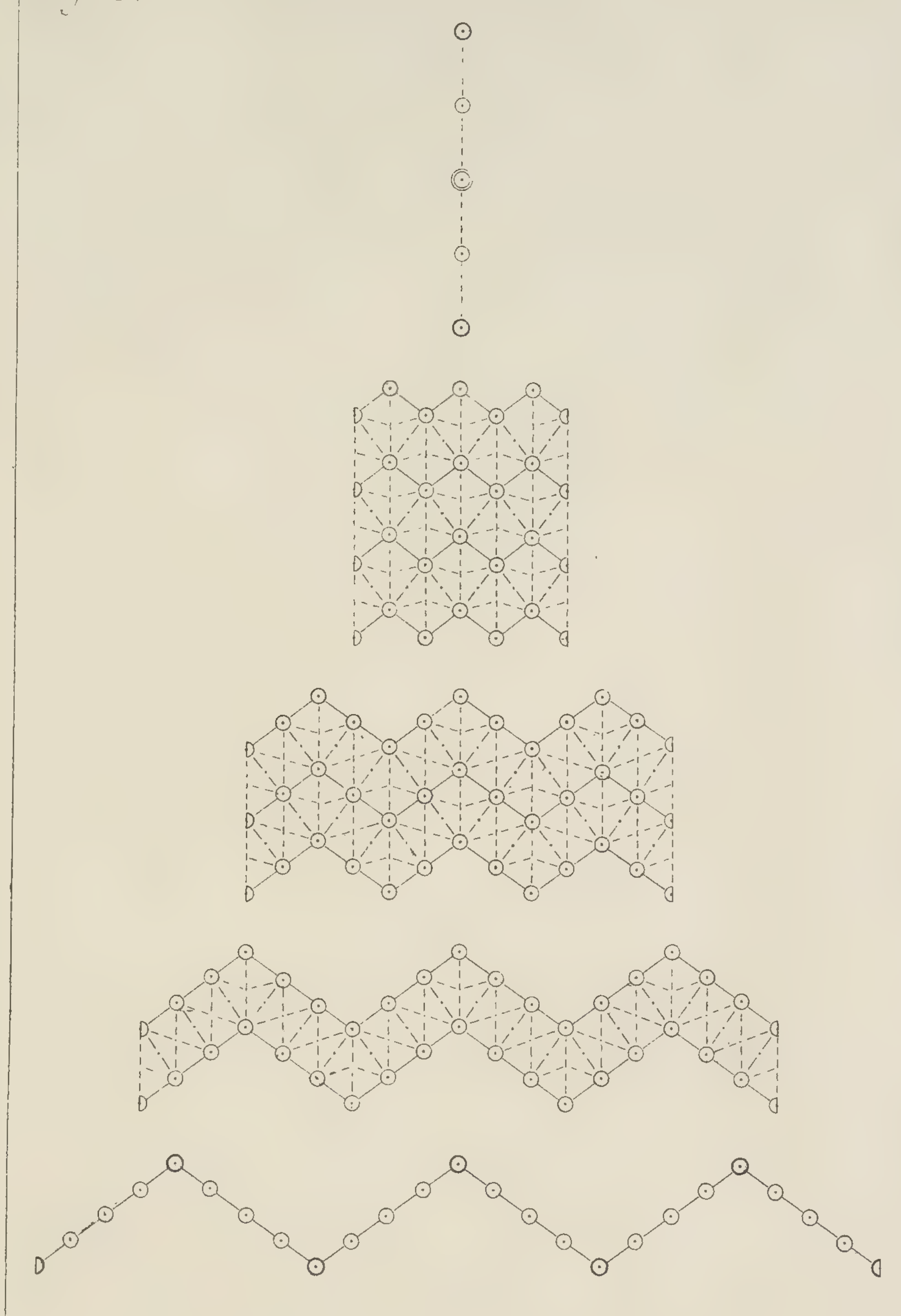
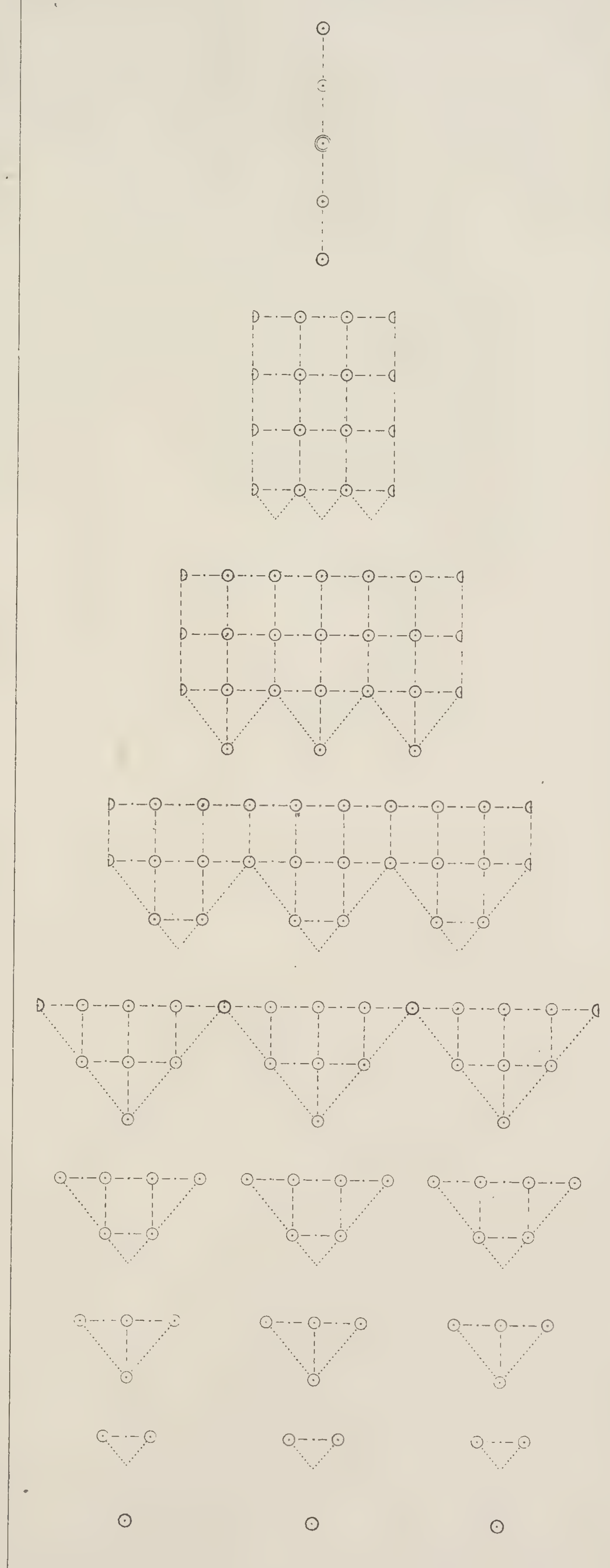
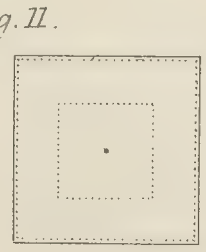


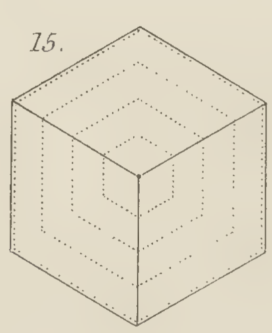
Fig. 16



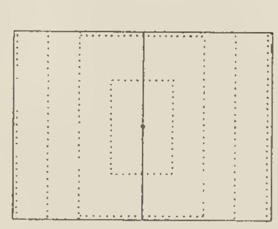
To Fig. 11.



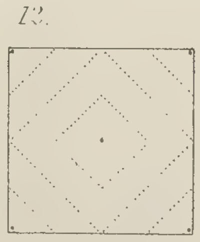
15.



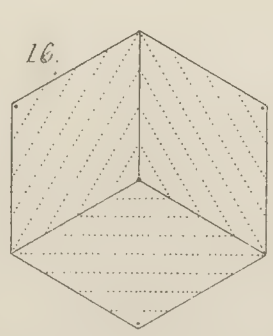
13.



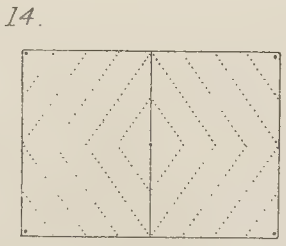
12.



16.



14.



CHAPTER IX.

OCULAR MODIFICATIONS OF COLOURS.

SENSATIONS excited by light continue for a certain time after their cause has ceased. Thus when a constant light begins to act on any part of the retina, it seems to grow stronger, until in a very short time it attains its full brightness, in consequence of each successive luminous wave adding its effect to the unexpired effect of former waves; and whenever the light suddenly ceases or moves to a new part of the retina, it leaves an image or spectrum of the luminous object, which gradually fades away. This is easily seen when the eye after steadily viewing something bright is suddenly enveloped in darkness; and it causes the luminous streak that follows such an object when it moves. The duration of this spectrum varies somewhat with the state of the eye and with the brightness of the exciting light; but unless the eye has been strongly excited it is but very short, and in that case the colour of the spectrum does not perceptibly vary from that of the light which produced it. But if the eye has been very strongly excited, the duration of the spectrum is much greater; and with extreme excitement it often changes colour, and sometimes even recurs again after having vanished, as is seen when the eyes from being directed to the disc of the sun are suddenly enveloped in total darkness.*

This self-action of the nervous tissues, commencing as soon as light impinges upon the retina, and continuing until the spectrum finally vanishes after the light has ceased, seems to be universally attended with a diminution of sensibility to the action of light, which produces a much more sensible effect. The best evidence of this is obtained by suddenly directing the eye, after fixedly contemplating any bright object on a black ground, to a uniform gray surface of moderate brightness. That part of the gray surface whose image occupies the part of the retina which was

* To see these effects the eyes must be not only suddenly closed, after viewing steadily the luminous object, but must be shaded from all light, the eyelids being but imperfectly opaque. If this is not done the effect is complicated with the circumstance mentioned in the next paragraph.

affected by the bright object, appears darker than the rest, and tinged with a hue complementary to that of the object. This (which is usually called the "accidental colour" of the object, and is often, though needlessly, attributed to a reaction in the eye) may always be observed as long as the ocular spectrum produced by the bright object can be seen in the dark; and when that changes colour, the spot to be seen on the gray surface changes also, so as to be always complementary to it in hue. Hence spring all those remarkable modifications of colours which have been elaborately treated of by Chevreul and others, under the designations "simultaneous contrast," and "successive contrast," and the knowledge of which is justly regarded of great practical importance; for in consequence of them some colours seem mutually deeper or clearer in juxta-position, while others seem duller. The law according to which all these effects are produced (the light not being greater than what the eye can easily bear), and by which we can always tell beforehand what effect will be produced when we look at two given colours in juxta-position, may be expressed as follows:—

The excitement of any one of the simple sensations of colour on any part of the retina is attended with a proportionate loss of sensibility for that same sensation.

As no colour (except Black) can be obtained perfectly free from mixture of White, the general effect is to cause each of the colours seen in juxta-position to appear more or less tinged with the complementary of the other, both in hue and in brightness. Thus a colour is deepened by its complementary, dulled by its like, and darkened by a brighter colour, as compared with its appearance when seen against Black. Darker surroundings have less effect, but only against a back-ground of perfect Black, the real colour appears in undiminished brightness.

By looking at a moderately shaded white surface through a perforation in a strongly coloured paper, the change of the White to the complementary of the colour of the perforated paper may be very clearly seen. The experiment may be varied by putting other coloured surfaces in the place of the white. The like modifications are still more strongly produced on parts of surfaces shaded from the light of a sunbeam that has traversed coloured glass. The same cause makes daylight appear blue, when it enters a chamber illuminated with the yellow light of lamps or candles; and produces many other phenomena, which an intelligent observer cannot but notice. It is obvious that a perfect acquaintance with the true complementary colours is the key to the practical use of this important principle in the Science of Colour.

The following Table of the mutual modifications of our imperfect representations by pigments of the eight principal colours may help to determine those of their

intermediate colours also. The colours as seen against Gray are taken as the standards with which the modified colours are compared, because that comes nearest to the conditions under which they are commonly seen, and it allows the apparent modification by Black to be stated: though in truth a perfect Black neither modifies nor is modified by any colour.*

COLOUR WHEN PLACED ON GRAY.	OCULAR MODIFICATIONS OF THE SAME WHEN PLACED							
	ON BLACK.	ON BLUE.	ON GREEN.	ON RED.	ON SEAGREEN.	ON PINK.	ON YELLOW.	ON WHITE.
Black.	Duller Black.	Yellowish Black.	Pinkish Black.	Seagreenish Black.	Reddish Black.	Greenish Black.	Bluish Black.	Deeper Black.
Blue.	Lighter Blue.	Duller Blue.	Pinkish Blue.	Seagreenish Blue.	Duller Pinkish Blue.	Duller Seagreenish Blue.	Deeper Blue.	Darker Blue.
Green.	Lighter Green.	Yellowish Green.	Duller Green.	Seagreenish Green.	Duller Yellowish Green.	Deeper Green.	Duller Seagreenish Green.	Darker Green.
Red.	Lighter Red.	Yellowish Red.	Pinkish Red.	Duller Red.	Deeper Red.	Duller Yellowish Red.	Duller Pinkish Red.	Darker Red.
Seagreen.	Lighter Seagreen.	Greenish Seagreen.	Bluish Seagreen.	Clearer Seagreen.	Duller Seagreen.	Duller Greenish Seagreen.	Duller Bluish Seagreen.	Darker Seagreen.
Pink.	Lighter Pink.	Reddish Pink.	Clearer Pink.	Bluish Pink.	Duller Reddish Pink.	Duller Pink.	Duller Bluish Pink.	Darker Pink.
Yellow.	Lighter Yellow.	Clearer Yellow.	Reddish Yellow.	Greenish Yellow.	Duller Reddish Yellow.	Duller Greenish Yellow.	Duller Yellow.	Darker Yellow.
White.	Clearer White.	Yellowish White.	Pinkish White.	Seagreenish White.	Reddish White.	Greenish White.	Bluish White.	Duller White.

* Except that it may sometimes be perceptibly tinged in the contrary way with the direct spectrum of a surrounding bright ground, as the eye glances from that to the Black.

CHAPTER X.

MENTAL EFFECTS OF COLOURS.

The mental effects which attend the three colour-sensations are difficult to define, though always more or less perceptible when we contemplate the colours in which those sensations severally predominate. Words that properly belong to other things are usually employed to describe them, such as exciting, lively, cheerful, warm, advancing, for the effect of Red ; refreshing, gentle, soft, and pleasant, for the effect of Green; and quiet, sober, cool, retiring, for the effect of Blue. In reality these are perhaps but different degrees of the same effect, and amount to no more than this, that Red is more exhilarating than Green, and Green more than Blue. If so, the fact may well be supposed to arise from the wave-periods and lengths being greater in the red rays than they are in the green, and greater in the green than in the blue; or from the actual force or *vis viva* of the waves being greater in the red than in the green, and greater in the green than in the blue, as experiments on the heating power of the prismatic rays have proved. A like difference may be observed in the effect of musical notes of lower or higher pitch.

To compare fairly the effect of different colours in this respect it seems most reasonable that all should be reduced to such degrees of brightness as to form equal contrasts with Black, which can have no positive effect; so that their places in the cube of colours would be all equally distant from the corner of Black. If, for instance, a set of primary and secondary colours, with those of the intermediate hues, and a neutral Gray, all so related, were arranged according to the average wave-lengths, or the average forces of the rays that produce them, they would stand somewhat as follows:—(1) Red; (2) Darkish Yellow-Red or Orange; (3) Dark Yellow or Olive Green, and Darkish Pink-Red or Crimson; (4) Darkish Yellow-Green ; (5) Green, Dark Pink or Purple, and a Lightish Gray ; (6) Darkish Seagreen-Green; (7) Dark Seagreen and Darkish Pink-Blue or Mauve; (8) Darkish Seagreen-Blue ; and (9) Blue: and most persons, it is probable, will concur in

thinking that these colours, arranged according to the liveliness of their effect, would stand in much the same order.

If we would compare in like manner the effects of the principal colours in their full brightness, White, Yellow, Pink, Red, would evidently take the first rank in liveliness as well as force; and then Seagreen, Green, Blue, Black. In mental effect there is thus the nearest affinity between Yellow and White, and between Blue and Black.

It is also remarkable that there is a more conspicuous variety in the assemblage of colours in which Red predominates, than in those in which Green and Blue predominate; or, in other words, there is more apparent difference between Red and Blue, and between Red and Green, than there is between Green and Blue. This adds to the vivacity of compositions in which colours allied to Red prevail, and to the quietness of those from which they are excluded; as may be seen in the various arrangements of colours given in Chapter VIII.

CHAPTER XI.

THE HARMONY OF COLOURS.

If the harmony of colours is proved by the pleasure which they give when viewed in succession, or side by side, and when viewed in combination, then the three simple colours must be considered as eminently harmonious. Each of them separately is beautiful, pleasing the eye especially on its first appearance after darkness, but their beauty is increased and lasts longer when they are presented in couples one after another, as when the Red and the Green, the Green and the Blue, or the Blue and the Red prismatic rays are caused to enter the eye side by side without the rest, and the eye is rapidly directed from one to the other; and they give still greater and more lasting pleasure when all three in like manner are presented side by side or in succession to the eye. When seen in conjunction, again, they are equally beautiful, whether presented in pairs, as in Yellow, Seagreen, or Pink, or altogether, as in pure White; nor is their beauty lost in either case though one is presented in greater strength than another, as in the intermediate hues, and indeed in all colours which are not perfectly neutral, no colour being without some mixture of white. It is also very remarkable that the more nearly neutral the colour is with the same degree of brightness, the longer can the eye contemplate it with pleasure. It would seem as if, there being three kinds of nervous fibres, or three modes of action, one for each simple sensation of colour, alternations of rest and excitement in each of them give pleasure; for such a supposition sufficiently accounts for the principles of the harmony of colour without assuming that the excitement of one sensation creates a desire for the like excitement in the rest.

Whether there is or is not any relation between the periods of the vibrations which most powerfully excite the several simple sensations of colour, similar to that which exists between musical notes in the same octave, has not, it seems, yet been conclusively shown. The wave-periods of those rays which appeared in Mr. Maxwell's experiments to present the deepest Red, Green, and Blue, though not

forming any harmonical series, do not differ very widely from the series $1, \frac{4}{5}, \frac{2}{3}$, or that of the musical notes, C, E, and G, the simplest and best of any series of three that can be found within an octave. To form that series the extreme terms should be more distant from the mean. But owing to the weakness of the light near the ends of the spectrum, it seems probable that the relative depth of colour in the Red and Blue rays falling outside of those mentioned above is not accurately determined by the experiments, and it is not easy to persuade the eye that the depth of colour is really less in those outer rays. Hence it may yet be possible that the same relation exists between Red, Green, Blue, in colour, as between *do*, *mi*, *sol*, in music; and it must be admitted that not only the analogy between light and sound, arising from their vibratory nature, but also several circumstances attending the sensations excited by light, make it probable that such a relation does really exist. Moreover there is evidently a greater difference between Red and Green, and between Red and Blue, than there is between Green and Blue; which corresponds with what is true of the notes C and E, C, and G, and E and G. But it does not seem that the sequence of colours in the spectrum can be explained on these principles without supposing that the sensation of Red is also excited in a minor degree by vibrations an octave higher than those of the C, and the sensation of Blue by vibrations an octave lower than those of the G.

If this idea of the harmonical relations of colour is true, the eye might be compared to a musical instrument of three strings, tuned to give out those notes only; and that all possible variations of colours correspond to sounds which are symphonies of these notes only, sounded in various degrees of intensity. But in any case, since the three simple sensations, as before stated, are beautiful and pleasant to the eye, both separately and simultaneously, in succession or in combination, it seems clear that (strictly speaking) that there can be no discord in colours.*

There are, however, different degrees of pleasure derived from different successions or combinations; and though any variation is preferable to unbroken uniformity, some are far more agreeable than others. The chief grounds of excellence will perhaps be found in the following points:—

* Some consider that there are colours which, when seen side by side, produce a disagreeable and even painful impression, and therefore maintain the existence of real discords in colour. But conceive the eye viewing a continuous surface of some uniform brightness and hue; it is hard to suppose that the introduction of any variety in either quality could then take place without being contemplated with positive pleasure (supposing of course that the eye is not too strongly excited). However great the charm of a good composition in colours, and the disappointment felt by the educated eye at the want of that charm in other compositions, I am persuaded that the difference is merely one of degree, and that no two colours produce together a positively unpleasant effect.

(1.) The due balance of the colours in quantity or strength, or the equivalence of the Red, Green, and Blue contained in the whole composition;

(2.) The symmetry, resemblance, or correspondence in nature and extent, of the gradations and contrasts in different parts of the composition;

(3.) The variety of the colours, and of the gradations and contrasts presented.

The first of these is carried out with the nearest approach to perfection when every colour is either accompanied with its perfect complementary, or with two or more other colours of such sort that the mean or average of the whole is a neutral Gray: the contrasting colours not being necessarily in juxta-position, but so conveniently arranged as that the eye may readily refresh itself by passing from one to another. If the colours do not quite neutralize each other, an excess of strength in some may be compensated by an increased quantity of others, with the like general effect. But it is not essential that this mean or average, which gives the tone to the whole composition, should be neutral, though it undoubtedly ought to be so for a composition which is to fill the eye for any long continuance. Much of the charm of small compositions, or transient effects, often arises from the predominance of some particular hue. Thus in a landscape, while Red and Green almost universally prevail in the objects below us and immediately around us, they are balanced by the brighter though paler blue light of the heavens and the distance, the tone of the whole being white; while bowers and rocks in nature, and compartments of dwellings in art, which are visited for a limited time, may owe much of their beauty to the prevalence (not too strong) of particular hues in their colours. Small compositions, again, such as flowering plants in nature, and pictures in art, may have great strength of hue in their general tone, and yet please the more in consequence; but if this effect is to continue, they should be balanced either by the general tone of the surrounding objects, or by other similar objects of an opposite tone at no great distance from them, to which the eye may turn for relief and fresh excitement. In such compositions, again, unity of effect is aided not only by the general prevalence of some hue, but also by giving prominence to some colour on which the eye will naturally rest more than on the others, and which will perform the same office as the key note in a musical composition.

The second point would be perfectly attained where colours change in all directions according to different laws of gradation, each of which continues the same in the same direction; a change which may take place with any degree of slowness down to that which is imperceptible. But the rate of change may be different in different directions; or it may vary in different places, even from nothing to infinity, in which case spaces presenting a uniform colour would adjoin to others presenting other uniform colours, and there would be contrast and no gradation. But it is not essential that every part

of a composition should exhibit the same sort of changes; on the contrary, if there are parts on which the eye is to dwell, and which give a character to the whole, they ought to be marked with peculiar changes in the gradations, or something singular in the contrasts. To this head, chiefly, belongs the beauty arising from evenness of colour and truth of gradation; also that arising from unity of design, which gives a character to the whole composition, as well as that arising from the distribution of light and shade, and of various hues, in such a manner as to make them naturally inhance each other's value, and increase the effect of the whole. In nature the principal gradations and contrasts are made in light and shade; and the important bearing which the disposition of these has upon the beauty of the scene is evident.

The third point, the variety of the colours gradations and contrasts presented, inhances the richness and charm of a composition, though it increases the difficulty of securing the satisfactory attainment of the two former points. Variety of colours involves first the distance of the extreme colours from each other, or from the mean or average colours; and its attainment in the highest degree requires the utmost possible depth and clearness in the extreme colours, as well as the greatest number of changes. Variety of gradations and contrasts involves not only the exhibition of gradations and contrasts between different colours, but also the exhibition of gradations of various degrees of quickness, from that which is imperceptibly slow, or the continuation of uniform colour, to that which is infinitely quick, or the juxta-position of different colours.

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CHAPTER XII.

APPENDIX ON DICHROMISM AND DEFECTIVE COLOUR-VISION.

DICHROMISM.

There are many persons (far more, at least of the male sex, than is usually supposed), who though they see all the prismatic rays usually visible, can distinguish in them only two different hues. The rays which to the ordinary trichromic vision are red, as well as those which are green, almost always appear to such persons of the same hue with the yellow rays that lie between them; the seagreen rays appear gray, and the blue and violet appear blue. Hence it is evident that they are capable of only two sensations of colour, which are complementary to each other, and are doubtless identical, or nearly so, with the Yellow and Blue of ordinary eyes. All natural objects are of course in their eyes coloured accordingly. A bright scarlet like that of Red-lead, and a green, like that of Emerald Green, and even the brilliant red and green signal lights used on railways, are to such persons indistinguishable in hue, and differ from the colour of the clearest yellow pigments in depth alone. Verdigris is indistinguishable from a shade of White, and so also is a certain compound of Red and Blue, if the Red predominates (for the red rays affect eyes of this kind less strongly with the sensation of Yellow than the blue rays with the sensation of Blue, as is evident from the fact that Rose Madder usually appears to them a good pale Blue, and Crimson lake, or even Carmine a dark dull Blue). Good Yellows on the contrary, affect such eyes, in all probability, with a deeper or stronger sensation of Yellow than can be excited in the ordinary eye; and what is white to the one kind of vision is the same to the other, so that in the whole spectrum the collected strengths of Yellow and Blue are equal.

All the possible variations of colour in this kind of dichromic vision may be comprized within a plane rectangle, whose opposite corners are Black and White, and Blue and Yellow; like that medial section of the cube of colours which is given in Series 9, (page 29).

Besides this, there may be another kind of dichromic vision, for Dr. G. Wilson* mentions one person who did not distinguish Chrome-Yellow and Orange from Pink and Crimson, which could hardly be if he distinguished Green and Blue; so that Red and Seagreen were perhaps his only two sensations.

It may be noticed also that some cases are recorded in which it seems that there was no distinction of hue, and the only difference in the appearance of surfaces consisted in brightness. But these, like the last, do not seem to have been sufficiently investigated; and if they really exist, apart from defective colour-vision, are rare.

DEFECTIVE COLOUR-VISION.

There are also many persons who appear to be wholly or partially insensible to rays belonging to the less refrangible end of the spectrum. This defect is most common amongst persons of dichromic vision, but is not confined to them; since some who are almost insensible to the red rays in general, are able to distinguish Yellow and Green, and, with a very strong light, Red also. To such persons deep Reds are almost indistinguishable from Black. Candle-light, from the small proportion of Blue rays which it contains, is much darker to them than to others; and the rays emitted by heated substances become luminous only at higher temperatures. It is easy to see that this defect must alter the apparent colours of all objects, and unless accompanied with some corresponding difference of capacity for another colour-sensation, must make them approach in hue towards Seagreen or Blue. Use, however, makes almost unnoticeable any universally predominant hue; as we still call those surfaces white which reflect all the luminous rays, though when seen by candle-light they are really yellow.

A less common defect is want of due sensibility to the more refrangible or violet rays; and this has been found to occur in some instances by itself, and in others, conjoined with the former defect. These peculiarities vary much both in extent and character.†

* Treatise on Colour-blindness (Edinburgh, 1855).

† See a Memoir by Dr. E. Rose, of Berlin, translated in The Phil. Mag., February, 1866.

THE END.

Nearly ready for the Press, by the same Author,

COLOUR-LORE,

AN INTRODUCTION TO THE SCIENCE OF COLOUR.

It is the object of this work to recount the principal theories, observations, and discoveries that have been made about colours, from the earliest ages to the present time, and then to discuss more fully several points which hitherto, as the author believes, have been either unnoticed or very imperfectly treated. But since colours are effects produced in the eye by the different rays of light, their study is necessarily connected with that of the nature of those rays, and their action on the eye, touching upon that wonderful chain of causes and effects through which it has pleased Him, who said, Let there be light, to present the image of His glorious creation to our minds, not under the plain garb of a simple light and shade, but adorned with the resplendent beauty and ever-changing charms of a three-fold system of colour; and to assist the reader to see the true bearing of the discoveries which have been made from time to time about colours, as well as on account of the intrinsic interest of the subject itself, a comprehensive popular outline in logical order of the whole science of etherial waves, and especially of light and its action on the eye, has been added by way of introduction. Thus the work will be comprized under the following divisions:—

PART I.

AN OUTLINE OF THE SCIENCE OF LIGHT.

Chap. I. Elasticities of bodies in general, and the origination and propagation of waves of normal and of transverse vibration in a medium filling space. Illustrations and examples of such waves.

Chap. II. The nature of light. The constitution of the ether, both free and in conjunction with matter, necessary to account for the phenomena of light.

Chap. III. The origination of luminous waves. What is intended by Rays of light. Distinctions of rays, (1) as to the periods of their waves, attended with distinctions of colour; (2) as to the directions and forms of their vibrations.

Chap. IV. Diffraction, or the lateral spreading of a luminous wave partially intercepted, and the consequent divergence of rays of light.

Chap. V. Dispersion, or the unequal retardation of waves of longer and shorter periods, in material media.

Chap. VI. Refraction and Reflection, or the formation of new compound waves when luminous waves impinge on the surface of a new medium. The forms of the new wave-surfaces in the two media, and consequent directions of the reflected and refracted rays. Effects of mirrors, and of lenses and prisms; colours arising from refraction. The refractive and dispersive powers of bodies.

Chap. VII. Refraction and Reflection continued. The modifications in direction, form, and intensity of the resulting vibrations in the new waves. Colours arising from reflection in two ways. Effects of the texture of bodies.

Chap. VIII. Plane polarization and double refraction of light by certain media.

Chap. IX. Circular polarization and double refraction of light by certain media.

Chap. X. The interference of waves. Its exhibition in various simple cases of diffraction, reflection, refraction, and double refraction. Colours arising from interference in different cases.

Chap. XI. Absorption, or the gradual extinction of luminous waves by material media, the principal cause of the proper colours of bodies. Fluorescence and other phenomena attending absorption.

Chap. XII. The action of light on the eye; the sensations of colours produced by it; trichromic vision; the three simple sensations, and their compounds; dichromic vision; defective colour-vision; the blending of the sensations excited in the two eyes; irradiation; the continuance of the sensations excited; the changeableness of those excited by strong lights; the diminution of sensibility under the action of light.

Chap. XIII. Recapitulation of the causes of the variety of colours in nature; the importance of the study of the solar spectrum; the marvels of light; what has been learnt by the aid of colour, and what may yet be learnt.

PART II.

AN ACCOUNT OF THE PRINCIPAL OPINIONS, OBSERVATIONS, AND DISCOVERIES, ANCIENT AND MODERN, WHICH BEAR UPON THE SCIENCE OF COLOUR.

Chap. I. Opinions of the ancient philosophers, as stated by Plato, Aristotle, Lucretius, Seneca, Pliny, Ptolemy, and others. What was known to Alhazen, Vitello, Albertus Magnus. Leonardo da Vinci's remarks on colours. The revival of learning and commencement of experimental philosophy. Kepler, De Dominis, Snellius, and Descartes. The theory of Descartes. The old philosophy still maintained; Sir Kenelm Digby; Father Kircher; Zucchius, Fabri, Dechales. The observations and doctrine of Grimaldi. The views of Hooke; Boyle's experiments; his statement of the ignorance of his age about colours.

Chap. II. Newton's discoveries about light and colour. A summary of his experiments. His recapitulation of what they prove. His observations on the colours of bodies; his refutation of Hooke's opinion. His division of the prismatic colours. His rule for finding the colour of a mixture of any prismatic rays. Explanation of the theory of the rule. His experiments on the colours of thin plates. His measurement of the thicknesses producing the different colours. Deductions from these measurements. His queries on the cause of the sensations of colour.

Chap. III. Huyghen's views on the nature of light; his explanation of certain phenomena; his notion of the composition of colours. Euler's theory of light and colours. His thoughts on the nature of colours, on their analogy with sound; and on the way opaque bodies are rendered visible. Mayer's doctrine of three primary colours; its adoption by Scheffer and others. Lambert's observations on the intensities of natural colours; and on the brightness of surfaces; more recent results obtained by Seidel and Zöllner. Lambert's experiments on the combination of coloured lights; his table of the quantities of light reflected and transmitted by glass; his remarks on the prismatic colours. Delaval's experiments on the colours of bodies.

Chap. IV. The elder Herschel's observations on the illuminating powers of the prismatic rays. His discovery of invisible rays beyond the red rays. Ritter's and Wollaston's discovery of invisible rays beyond the violet rays. The importance of the invisible rays in the theory of colour. Wollaston's discovery of dark bands in the solar spectrum. His division of the colours. Young's observations on the same. The difference between Wollaston's and Newton's spectrum. The need of more exact definition of the colours. Young's observations on the colours of the simple and mixed prismatic rays. His method of exhibiting the combinations of colours. His theory of the cause of the colour sensations. His discovery of the interference of light; and measurement of wave-lengths. His suggestion that luminous waves are transverse. Fresnel's investigations; proof the wave theory.

Chap. V. Fraunhofer's survey of the prismatic solar spectrum. His plan of the dark lines. His curve of intensity of light. Considerations affecting this curve. Leslie's remarks upon it, and description of the prismatic colours. Herschel's description of the spectrum. Fraunhofer's grating spectrum; his determination of the wave-lengths of the principal lines. Mosotti on the grating spectrum.

Chap. VI. Brewster's researches on absorption. His theory of three kinds of light, Red, Yellow, Blue. The objections of other philosophers. The opinion of Professor Stokes; the result of other experiments; and on the supposed primary colours. The utility of his idea of three overlapping spectra. His view of the cause of the colours of natural bodies. Herschel's experiments on absorption. His remarks on the different colours of different thicknesses of absorbing media. His suggestion as to the cause of absorption. Baron Von Wrede's theory of the same. Herschel on the green of vegetation; on the different colour sensations. His reasons for not rejecting yellow as a primary colour. His experiments on the effects of lowering the intensity of colored rays. Extract from Brewster and Gladstone on the colours of feeble light. Herschel's description of a method of analysing natural colours.

Chap. VII. First notices of fluorescence by Herschel and Brewster. Stokes' discovery of its nature. Its effect on the apparent colours of bodies. Early theories as to the cause of colours of bodies. Oersted's theory of two kinds of reflection. Its defects. Provost's theory of reflection, superficial and internal. Its defects. His mode of exhibiting the pure colours of bodies. Arago's mode of distinguishing the lights coming from a body. Haidinger's discovery of complementary colours from reflection and absorption. Stokes' discovery of the opacity of bodies to their colours by reflection. His exposition of the causes of the colours of bodies. The analysis of those of Permanganate of potash.

Chap. VIII. Dove's observations on the difference in the relative brightness of coloured surfaces under

power of colours; his standard of colours. The fallacy of such experiments. The mischief of false theories. Reasons for not detailing certain other theories and experiments. Fanciful analogies between colours and musical notes. Hasty deductions from unguarded experiments. Recent endeavours to overthrow the Newtonian doctrine. Goëthe's notions about colour. The truth of nature superior to all mistaken theories.

PART III.

AN ESSAY ON SEVERAL POINTS IN THE SCIENCE OF COLOUR WHICH SEEM TO REQUIRE FURTHER NOTICE.

No pains have been spared to make the proposed work complete and trustworthy, in the hope that it may be an accepted compendium of what is known on a subject in which, interesting and useful as it is, information has now to be sought from a multitude of sources, and much baseless theory has been reiterated. It has been the occupation of those working hours which the author has been able to spare from the calls of business, pupils, and family, for many years; the books consulted would form a considerable library, but the literature of the subject has not taken more time than those experiments and original researches by which he has been divested of many preconceived notions, and has been led, he believes, nearer to the truth of nature on this beautiful and inviting subject.

Aware, however, of several deficiencies which he has not been able to supply, and fearing there are many more, he would be much obliged by any kind suggestions or the loan of any work which may seem, from the above abstract, to have escaped due notice. There are several German books which he has not been able to meet with, such as Lambert's "*Farbenpyramide*," 1772, and Wünsch's "*Versuche über die Farben*," 1792. Any suggestion from colourists, also, as to the best means of representing the colours intended to be represented in the coloured diagrams in the present treatise, will be thankfully received.

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BENSON ON COLOUR.